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An analysis of ground maneuver concentration during NTC deliberate attack missions and its influence on mission effectiveness

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THESIS

AN ANALYSIS OF GROUND MANEUVER CONCENTRATION
DURING NTC DELIBERATE ATTACK MISSIONS
AND ITS INFLUENCE ON MISSION EFFECTIVENESS

by

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September 1989

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An Analysis of Ground Maneuver Concentration during NTC Deliberate Attack Missions and its Influence on Mission Effectiveness

by

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Submitted in partial fulfillment of the
requirements for the degree of

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September 1989

ABSTRACT

This thesis analyzes deliberate attack missions conducted at the U.S. Army National Training Center (NTC) and checks for relationships between ground force concentration at a battle point of critical attrition and a mission measure of effectiveness (MOE). This analysis should facilitate the development of deliberate attack mission training standards and the monitoring of unit performance in the area of force concentration or massing of combat power. Graphical methods and analytic techniques are developed to describe a point of critical attrition in the battle and various measures of force concentration. The thesis also describes the tank and mechanized infantry task force, the NTC environment and data collection characteristics, accuracy screening techniques for NTC data, and the deliberate attack mission.

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I. INTRODUCTION

A. BACKGROUND

The National Training Center (NTC), located at Fort Irwin, is situated in southern California, midway between Las Vegas and Los Angeles. Since the establishment of NTC, in June 1981, U.S. Army combat units have deployed to this training area to experience a tough, realistic exercise designed to prepare them for the first two weeks of an actual conflict. Deploying units become the Blue Force (BLUEFOR) and conduct combat operations against an Opposing Force (OPFOR). This exercise is the closest simulation of actual combat currently available to these units. One of the missions of NTC is to provide a data source for Army training, doctrine, organization, and equipment improvements. This mission is accomplished by recording various forms of data which describe the "what" and "why" of unit performance at NTC.

One deficient NTC maneuver trend, that has been recognized since 1982, is the inability to concentrate overwhelming ground combat power against the enemy during attack missions. NTC Training Observations, Volume II, released in September 1982, describes this trend:

> There is a general misunderstanding of what it means to concentrate overwhelming combat power.... The importance of isolating portions of the enemy and overwhelming him in detail while fixing the remainder of his force with the minimum force necessary is generally not practiced. Frontal attacks occur too often rather than flank attacks which concentrate the task force on platoons and roll up the enemy from the flank.... Attacking forces are subject to killing

> fires of the defender because shock, mass, and a heavy volume of fire cannot be generated. [Ref. 1: p. C-5]

The above performance trend has continued. When looking at observer comments about recent NTC attack missions, the term "piecemeal attack" is prevalent. At the National Training Center Trendline Analysis (NTC TLA) Briefing conducted on 14 June 1988, GEN Thurman, Commanding General of the U.S. Army Training and Doctrine Command (CG TRADOC), was particularly interested in maneuver synchronization. GEN Thurman wanted to identify ways to increase both tank participation and unit massing of fires [Ref. 2: p. 3]. At the May 1989 NTC Trendline Analysis Update, the U.S. Army Armor School concluded: "massing combat power appears to pay off substantially." This was based on a subjective evaluation of the comments and data of 72 NTC battles [Ref. 3].

B. PURPOSE AND SCOPE

Analysis efforts in ground maneuver synchronization at NTC have so far been very qualitative in nature. No formal study has been done on this subject. Observers and analysts have recognized that a deficient trend exists, but there is little quantitative analysis of "what happened" to reinforce the qualitative analysis of "why it happened." BG Funk, Commanding General, National Training Center and Fort Irwin, during a briefing on this thesis, 21 July 1989, stated that units preparing for NTC would benefit from more specific mission training standards. This thesis is a quantitative analysis of selected NTC battles with respect to ground maneuver synchronization to determine performance measures in this area. This, in turn, will help identify ground maneuver training standards to improve battle performance.

The scope of this thesis is narrowed by the following constraints and assumptions:

- Missions were conducted by Tank and Mechanized Infantry Task Forces with different equipment mixes (description in Chapter II).
- Battles were conducted under the NTC physical and operational environment (description in Chapter III).
- Only selected deliberate attack missions were analyzed during the Fiscal Year (FY) 1987 and 1988 time period.
- Results are derived from "post-battle analysis" of killed and live vehicle data (description in Chapters VII and VIII).
- Attrition data used from the Screened Kill Event Table (SKET), described in Chapter IV, Section C is assumed to be a representative sample of the actual attrition events from each mission.

Any extrapolation of the analysis results outside these considerations has not been validated and could lead to inaccurate conclusions.

C. PROBLEM DESCRIPTION AND HYPOTHESIS

Using *Task Force Deliberate Attack Missions* conducted under *NTC Conditions,* during Fiscal Years 1987 and 1988, the following synchronization factor will be analyzed and its influence on *Mission Effectiveness: Concentration* of *Ground Maneuver Forces* at the *Battle Point of Critical Attrition.*

Once all highlighted concepts in the above problem statement are defined, the following hypothesis will be tested for validity using data analysis: Given a task force deliberate attack mission conducted under NTC conditions, there exists a relationship between the degree of ground force concentration at the battle point of critical attrition (predictor variable) and a mission's measure of effectiveness or MOE (response variable) as shown in Figure 1. Such a relationship can lead to quantified task force training standards for ground force concentration during deliberate attack missions.

THE FOLLOWING RELATIONSHIP EXISTS:

DEGREE OF GROUND FORCE CONCENTRATION AT BATTLE CRITICAL ATTRITION POINT (Predictor Variable)	$\longrightarrow$	TASK FORCE DELIBERATE ATTACK MOE (Response Variable)

Figure 1. Thesis Hypothesis

II. THE TANK AND MECHANIZED INFANTRY BATTALION TASK FORCE

The U.S. Army unit which is the focus of training at NTC is the Tank and Mechanized Infantry Task Force, also known as a "heavy" task force. Understanding the organization and function of this unit is key to the analysis of NTC ground maneuver synchronization. The following chapter describes this flexible unit and its role in the employment of Air-Land Battle doctrine. This brief description is intended only as an introduction to a very complex organization. More detailed information can be found in Field Manual 71-2, The Tank and Mechanized Battalion Task Force [Ref. 4].

A. ORGANIZATION

The composition of the battalion task force can vary, depending on its mission. Task force organization is based on the following definition:

> <u>Battalion Task Force</u>: A force generally organized by combining tank and mechanized infantry elements under a single battalion commander to conduct specific operations. A battalion task force may be tank-heavy, mechanized infantry-heavy, or balanced, depending on the concept and plan of operation. [Ref. 5: p. 1-10]

The sub-elements of the task force are companies from pure tank and mechanized infantry battalions, which are cross-attached or mixed to form a battalion task force. The "tank-heavy, mechanized infantry-heavy, or balanced" refers to the ratio of tank versus infantry companies in the task force. This composition was further complicated in the 1987-1988 time period due to the Army's ongoing force modernization. All maneuver task forces which trained at NTC during this period were organized under the new J-series Table of Organization and Equipment (TO&E). However, most of these task forces had not received all their modernized armored vehicles and were still using non-modernized H-series TO&E equipment.

The J-series pure tank battalion, along with modernized and substitute non-modernized armored tank killing systems, is shown in Figure 2. The major subunits are four tank companies and the headquarters company (HHC), containing battalion support elements.

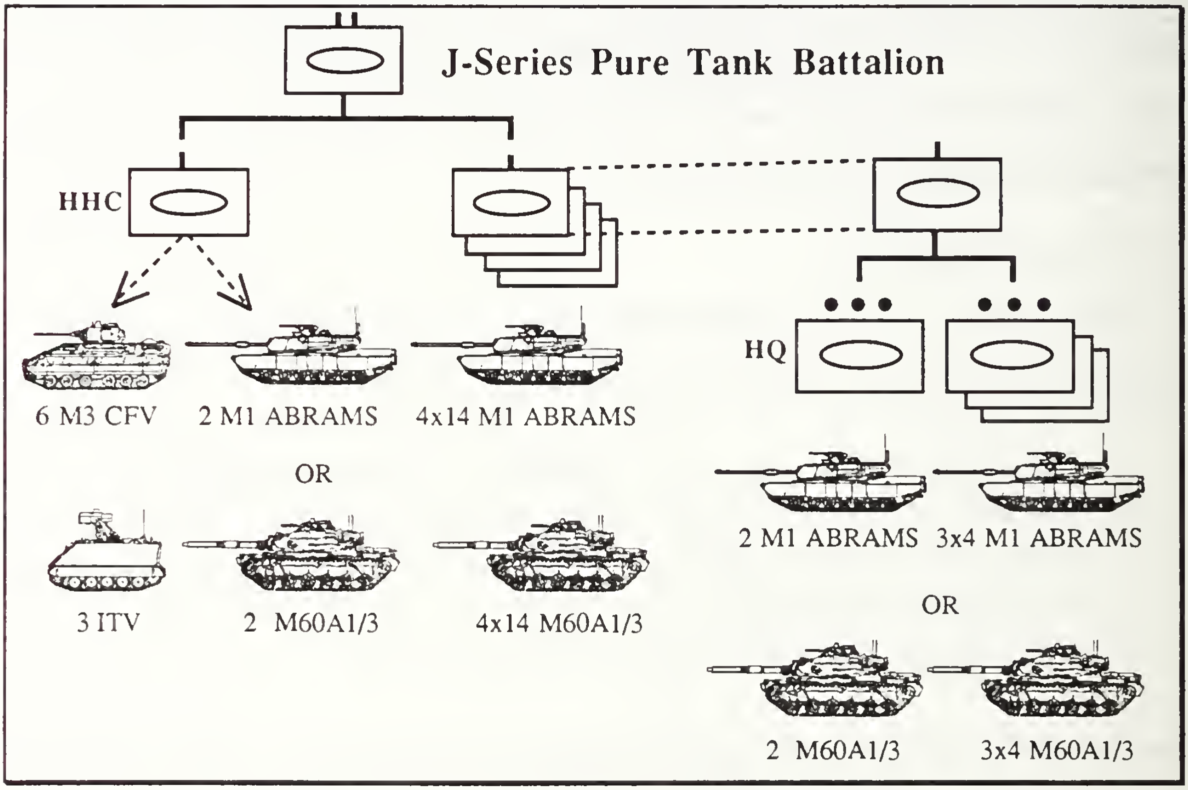

Figure 2. J-series Pure Tank Battalion

The J-series pure mechanized infantry battalion, along with modernized and substitute non-modernized armored tank killing systems, is shown in Figure 3. Until battalions received IFVs and CFVs, a smaller number of TOW vehicles (usually ITVs) were substituted as shown below. Major subunits are four mechanized infantry companies, an anti-tank company, and the headquarters company (HHC), containing battalion support elements.

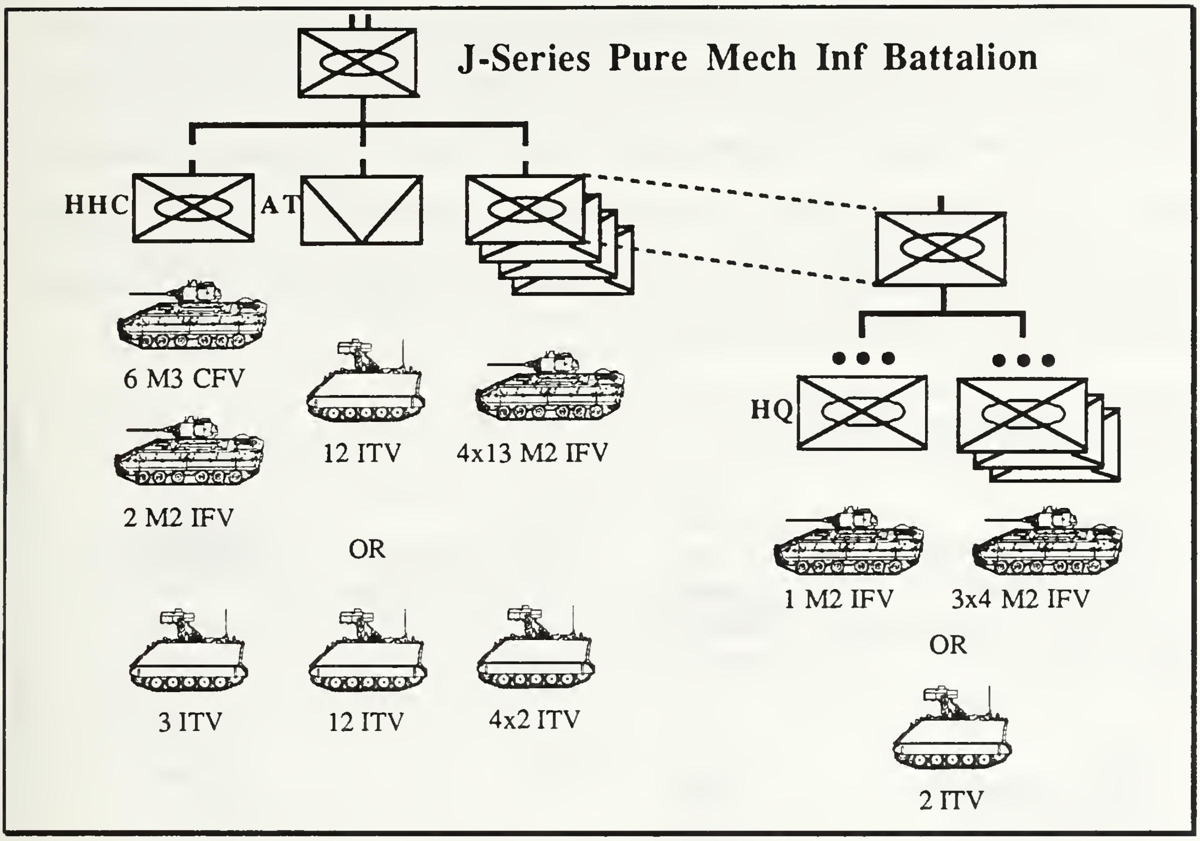

Figure 3. J-series Pure Mechanized Infantry Battalion

Totally non-modernized task forces equipped with M60A1 tanks and M113A1 TOW carriers trained at NTC during FY 1987 and 1988, as well as fully modernized task forces equipped with M1 Abrams tanks, M2 Infantry Fighting Vehicles (IFVs), M3 Cavalry Fighting Vehicles (CFVs), and Improved Tow Vehicles (ITVs). There were also high-low (modernized and non-modernized) task force mixes with M1 tanks and M113A1 TOW carriers. There were relatively few fully modernized task units which trained at NTC during this time period. [Ref. 6]

The brigade (higher unit) commander forms his task forces by cross-attaching companies from pure tank and mechanized infantry battalions, based on his estimate of the situation. Additional combat and combat support elements from brigade may also augment the task force. These additional elements include engineer, air defense, field artillery fire support, forward air control (FAC), as well as medical, maintenance, and logistical support teams. The task force commander's estimate, in turn, may require cross-attaching platoons from his tank and mechanized infantry companies to form company teams. A sample balanced task force task organization with augmentation is shown in Figure 4.

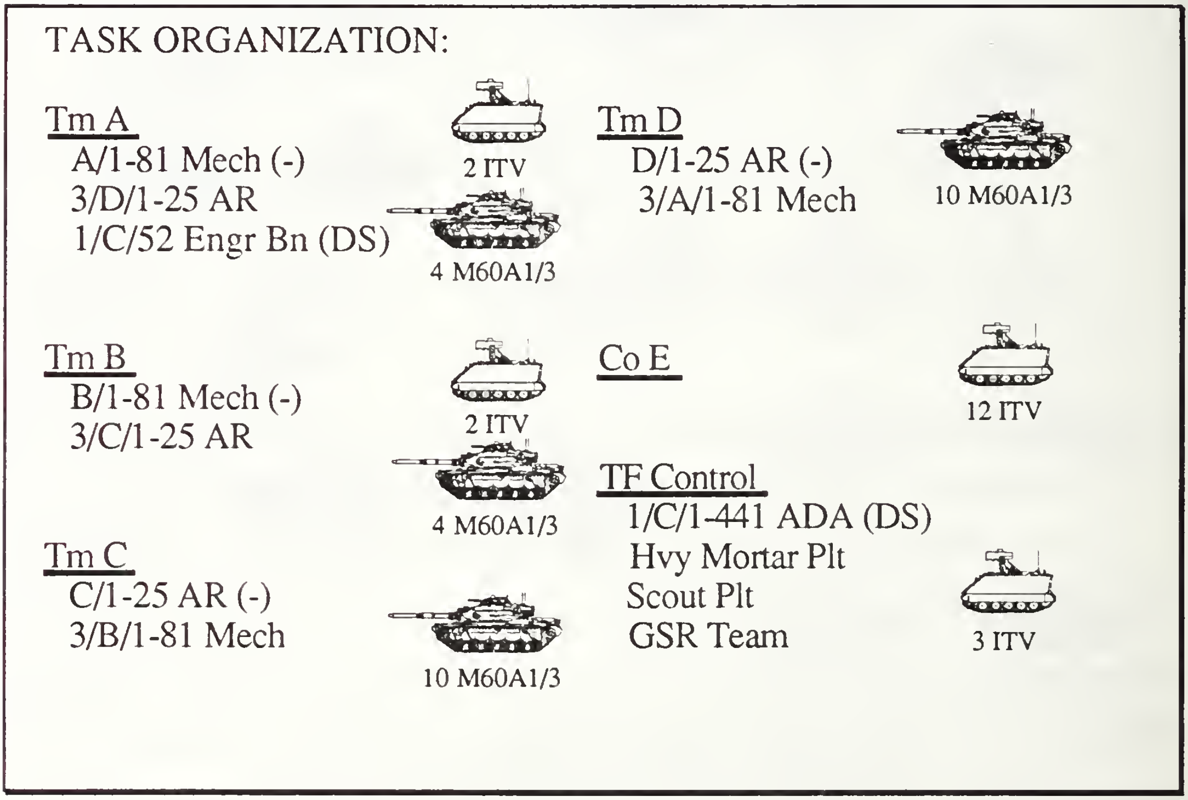

Figure 4. Sample Balanced Battalion Task Force Task Organization

B. COMPONENTS AND OPERATING SYSTEMS

There are interacting components within the battalion task force which determine its battlefield performance. Several key components are listed below:

- Battalion (Task Force) Commander: The task force is a reflection of his character. He must organize the task force based on the mission, enemy, terrain and weather, troops and time available (METT-T). Mission accomplishment is achieved by being aware of his resources and effectively employing them.

- Company or Team Commanders: These commanders directly employ the combat power of the task force through fire and maneuver. They must understand the battalion commander's concept and know how to employ their combat and combat support assets.

- Scout Platoon: This platoon is one of the primary sources of combat intelligence before and during the battle. It is not organized or equipped to conduct independent combat operations.

- Battalion Staff: The staff consists of the Executive Officer (XO), Adjutant (S1), Intelligence Officer (S2), Operations Officer (S3), Logistics Officer (S4), and special staff officers. They assist the commander by coordinating battle operations and also coordinating the combat support (e.g., artillery and engineer support) and combat service support (e.g., logistics and personnel) to ensure continuous operations.

    - The Executive Officer (XO) is both the chief of staff and second in command.

    - The Adjutant (S1) is responsible for personnel services and replacement.

    - The Intelligence Officer (S2) is responsible for battlefield intelligence collection, analysis, and dissemination.

    - The Operations Officer (S3) is responsible for preparing, coordinating, and disseminating tactical plans and orders.

    - The Logistics Officer (S4) is responsible for coordination of maintenance, transportation, and services.

    - Other special staff officers organic or assigned to the task force include the fire support coordinator and the Air Force forward air controller (FAC).

Functions of the task force are divided into seven battlefield operating systems (BOS). These operating systems must be integrated and synchronized by the various components of the task force to ensure mission success:

- Command and Control: Subordinates need to know the commander's intent and concept of the operation. During the battle, the commander should be located to best see and influence the battle and control his maneuver companies. They should not be overdependent on radio communication, since it can be disrupted at critical times.

- Maneuver: Tank and mechanized infantry companies maneuver to destroy the enemy and seize terrain. Attack helicopter companies maneuver to destroy the enemy and deny terrain. The synchronization of these companies in order to mass and bring overwhelming combat power against enemy weak points is crucial.

- Fire Support: The commander plans and coordinates field artillery, mortar, and close air support to suppress, neutralize, or destroy the enemy.

- Intelligence: The task force must use its dedicated scout platoon, infantry patrols, and attached ground surveillance radar (GSR) assets to collect and report priority enemy information before and during the battle. The brigade provides intelligence to the task force from other sources.

- Air Defense: The brigade usually provides Stinger or Vulcan air defense assets. These should be used in coordination with the task force's direct fire systems. Passive air defense measures, such as concealment, camouflage, and dispersion have to be practiced.

- Mobility, Countermobility, and Survivability: Engineer assets and all units perform engineering tasks, such as; digging fighting positions, preparing obstacles, and breaching enemy obstacles. The task force must survive under Nuclear, Biological, and Chemical (NBC) conditions by using avoidance and protection/decontamination assets.

- Combat Service Support: The battalion staff coordinates the manning, arming, fueling, fixing, transporting, and protecting of the task force. [Ref. 4: pp. 1-10 to 1-13]

C. ROLE ON THE AIR-LAND BATTLEFIELD

The task force's role in Air-Land Battle doctrine is maneuver warfare:

> In its simplest form, maneuver warfare involves using a part of the force to find, fix or contain the enemy, while the remainder of the force attacks his weakest point - usually a flank or the rear. *The goal is to mass enough combat power at the critical time and place* to destroy the enemy or threaten him with destruction, while preserving freedom for future action. [Ref. 4: p. 1-3]

The battalion is the smallest U.S. Army unit which combines firepower, maneuver, intelligence, and support. Its area of operations extends from less than 100 meters (in close terrain) out to five or six kilometers beyond the range of its indirect fire systems. In offensive operations (see Chapter V), the task force is expected to defeat a defending enemy company, while preserving its force in order to fight enemy battalion reserves. [Ref. 4: pp. 1-6 to 1-7]

III. NATIONAL TRAINING CENTER (NTC) OPERATIONS (FISCAL YEARS 1987 AND 1988)

A. PHYSICAL ENVIRONMENT

The National Training Center is situated in the Mojave Desert at Fort Irwin, approximately 35 miles north of Barstow, California. NTC spans 640,000 acres (over 1660 square kilometers) of land area; 430,000 of these acres can be navigated by wheeled and tracked vehicles. The left side of Figure 5 shows the reservation outline, mountainous regions, and the three principle land corridors used for training. The force on force (or engagement simulation) training is conducted mainly in the central and southern corridors. This area is magnified on the right side of Figure 5 and the primary training areas are identified.

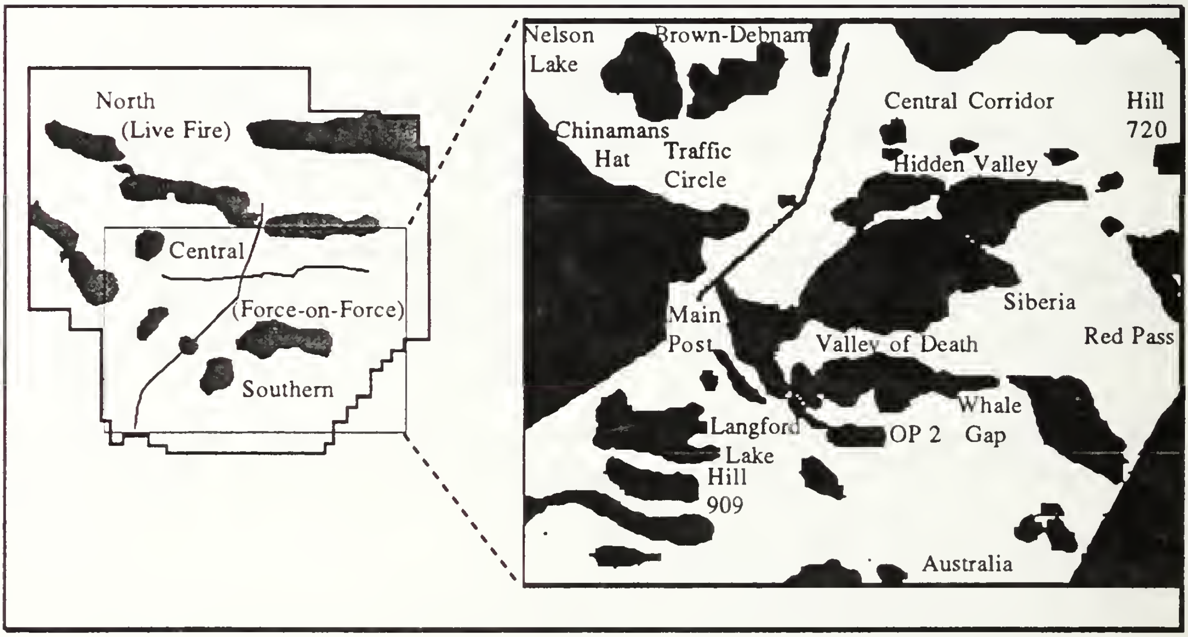

Figure 5. Fort Irwin Military Reservation and Force on Force Training Area

An excellent terrain analysis of each area, using the OCOKA (Observation and Fields of Fire, Cover and Concealment, Obstacles, Key Terrain, and Avenues of Approach) format is found in Root and Zimmerman [Ref. 7: pp. 14-22].

The weather varies from extremely hot and dry in summer to possible cold and wet conditions during winter months. During spring and fall, there are large temperature changes from day to night and high velocity winds. There is low humidity and a low yearly precipitation of about four inches, usually occurring during winter. The types of terrain include; flat, open areas, slopes cut by wadis and arroyos, defiles between mountains and hills, and significant mountain peaks and ranges. The effect of a lack of vegetation is negligible since the terrain does provide cover and concealment. The lack of water is a mobility training detractor since there are no permanent water obstacles. [Ref. 6]

B. OPERATIONAL PHILOSOPHY

The two missions of NTC are: to provide tough, realistic combined arms and joint services training in accordance with Air-Land Battle doctrine focusing at task force level, and to provide a data source for training, doctrine, organization, and equipment improvements. Training is "free play" to the maximum extent possible to force the unit to operate in an environment close to actual combat. Units are encouraged to learn from their mistakes and improve. The training atmosphere at NTC is one directed towards learning, not testing. [Ref. 6]

When looking at mission performance of task forces at NTC, the seven battlefield operating systems (BOS), described in Chapter 2, Section B, are used. Various forms of data are collected on unit performance, but the intent is not to determine which side won the battle. These data collection efforts must be transparent to the training effort by not impacting on the time, resources, or free play of the training unit.

After each mission, after action reviews (AARs) were facilitated by NTC personnel at levels of command ranging from platoon to brigade. The task force AAR was conducted about five hours after change of mission and was attended by the task force chain of command down to company commanders and the task force staff. The purpose of the AAR was to determine "what happened", "why it happened", and how to improve in future missions.

C. UNIT ROTATION DESCRIPTION

During the FY 1987 and 1988 time period, there were 14 rotational training periods (also called rotations) conducted per fiscal year at NTC. Table 1 shows a typical rotation schedule. Two task forces trained simultaneously during each rotation. The first two days consisted of drawing equipment and moving to the field. The next 14 days were dedicated to force-on-force training (FFT) and live fire training (LFT). During the last four days, equipment was turned in and the unit redeployed to its home station. Heavy task forces normally trained at NTC once every two years due to the limited number of rotations available and the number of units requiring training. [Ref. 6]

TABLE 1. TYPICAL NTC ROTATION

Day	1	2	6	11	16	20
TF 1	Arrive	FFT	LFT	FFT	Maint	
TF 2	Equipment Issue	LFT	FFT		Turn In	

D. THE OPPOSING FORCE (OPFOR)

The Opposing Force (OPFOR) at NTC is designed to replicate a threat motorized rifle regiment (MRR), which typically consists of three threat motorized rifle battalions (MRBs). During FY 1987 and 1988, the OPFOR consisted of two permanently assigned U.S. heavy maneuver battalions along with forward support, engineer and electronic warfare assets. These OPFOR units were augmented by dismounted infantry and combat engineers each rotation. An OPFOR motorized rifle battalion and motorized rifle company, along with their principle combat vehicles are shown in Figure 6.

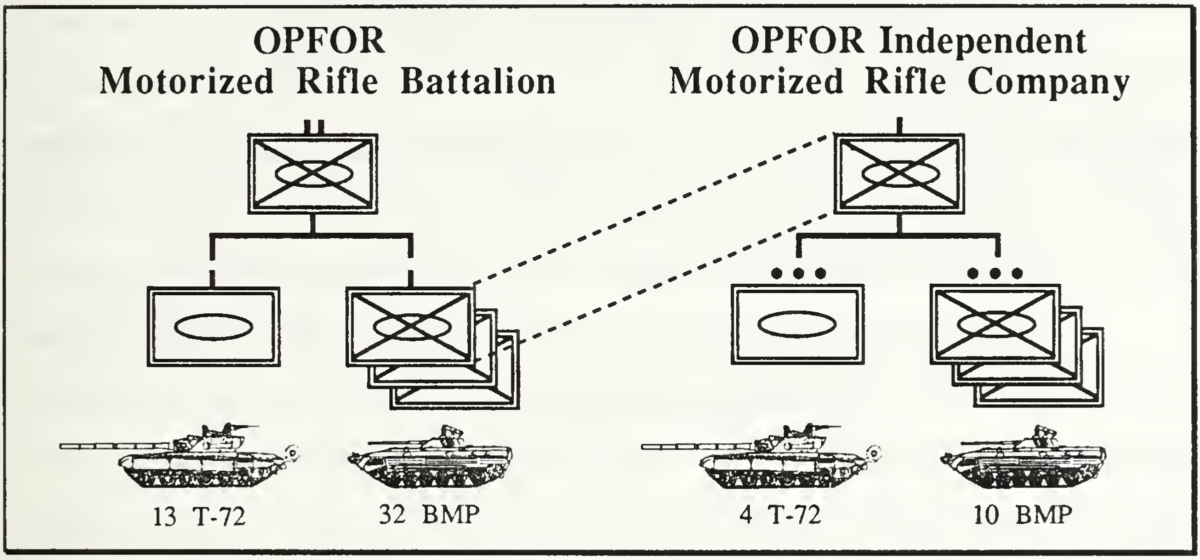

Figure 6. OPFOR Motorized Rifle Battalion and Independent Motorized Rifle Company

Visually modified tracked vehicles (VISMODs) were used to replicate threat T-72 and BMP tracked vehicles. The M551 Sheridan Armored Reconnaissance Airborne Assault Vehicle was used as the chassis for these VISMODs. Some actual threat vehicles were also used, primarily for infantry carriers.

The OPFOR is a tough opponent. OPFOR units spent over 200 days in the field each year training and performing against BLUEFOR task forces. Few of these BLUEFOR units had the time or resources to train this intensely. This field training time also gave the OPFOR the advantage of being very familiar with the NTC terrain and proficient at replicating Soviet tactics.

E. INSTRUMENTATION SYSTEM

1. General

The NTC instrumentation system consisted of three major subsystems during FY 1987 and 1988; the Core Instrumentation Subsystem (CIS), the Range Data Measurement Subsystem (RDMS), and the Range Monitoring and Control Subsystem (RMCS), as shown in Figure 7. The following NTC instrumentation description is limited to the CIS and RDMS components, which provided data during force-on-force training on the location and simulated engagements of armored ground tank killing systems (tanks and mounted anti-tank missile systems).

The Range Data Management Subsystem (RDMS) collected and provided data of real time position locations, engagement events and vehicle status to the Core Instrumentation Subsystem (CIS). This data was collected in the RDMS by the C unit which controlled the interrogation of more than 40 repeater or A units located throughout the training area. Data was then relayed to the CIS for processing and storage.

2. Player Unit Component (PUC)

The key to the RDMS was the player unit component (PUC), also called a B unit. The PUC included the Multiple Integrated Laser Engagement System (MILES), which was aligned to the vehicle's direct fire system. MILES was used to resolve direct fire engagements during battles. MILES components included; an eye

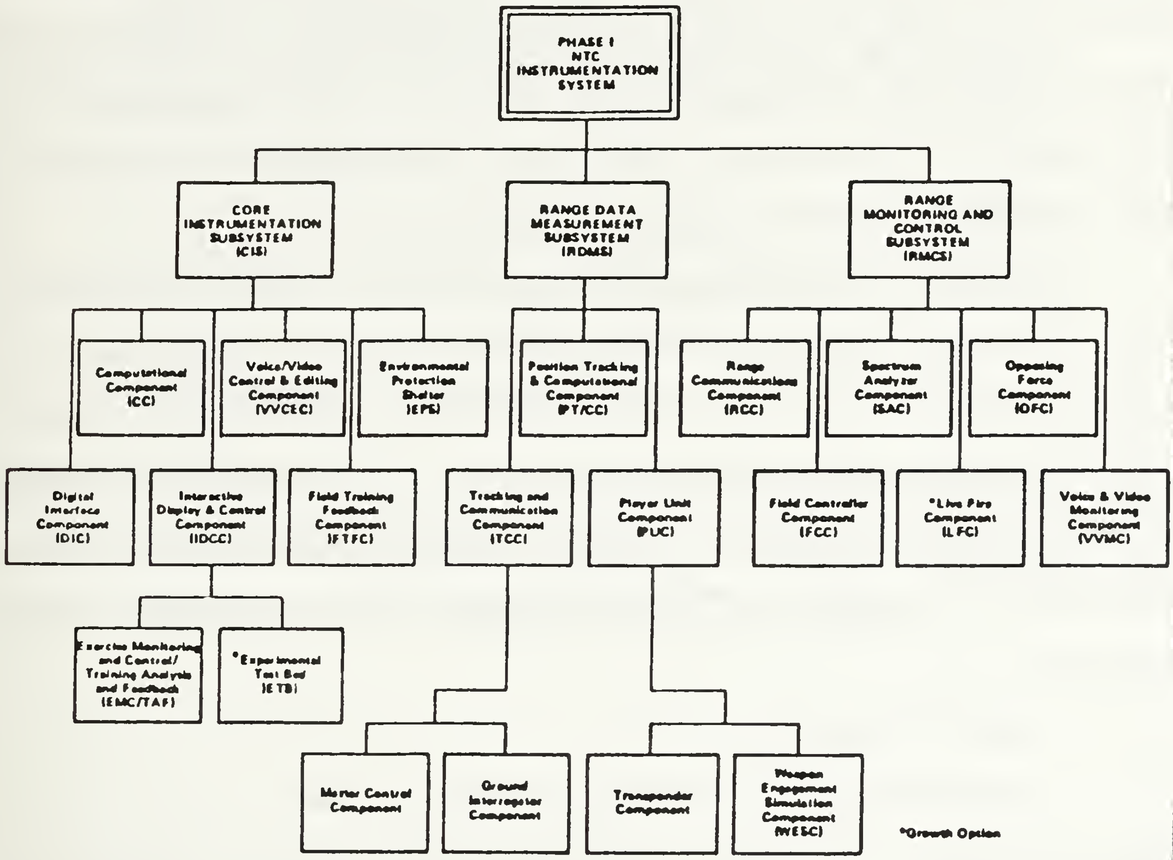

Figure 7. NTC Instrumentation System

safe laser transmitter used to produce coded laser pulses simulating the weapon effect, a pyrotechnic device to simulate the firing signature, and mounted detectors which received coded pulses from other players and determined the weapon type, accuracy, and probability of kill of incoming direct fire. The vehicle crew is instantly aware of a kill, near miss, or hit to its system by audio and visual means. The number of MILES engagements allowed in a battle was based on the ability of the unit to resupply the pyrotechnics which simulated live ammunition. If a weapon's MILES failed during a battle, it was administratively killed.

All armored tank killing systems participating in a battle had a complete PUC. However, ground mounted TOW and DRAGON tank killing systems, as well as machine guns and small arms, only had MILES. In addition to MILES, the PUC included transmitter and interface equipment. The complete PUC would transmit all MILES events and also a signal known as a range pulse for location determination. In addition, the PUC could receive commands to abandon or reset its MILES.

3. Data Collection

Transmitted MILES event data (including kills, hits, near misses, and trigger pulls) from a PUC required relay through only one A unit in order to be collected and passed to the CIS mainframe computer. An instrumented player could also be killed in other ways. NTC observer controllers (OCs), working with personnel at the CIS would assess casualties caused by indirect fires and minefields, and use a hand-held MILES laser (god gun) to kill systems. Also, a system could be administratively killed or re-keyed directly from the CIS.

The pairing of players in a direct fire engagement and a player's position location required more complex methods. A time coincidence pairing system was used to determine which vehicles were involved in a direct fire engagement, since there was no positive link between the actual firer and target in the field:

> The times of vehicle firings and time of vehicle reaction to MILES events (i.e., near miss, hit, kill) were all recorded on the RDMS to within the nearest millisecond. If one instrumented vehicle shot at a certain time, and another instrumented vehicle died within 5 milliseconds of the shot, the main frame computer went through a series of subroutines to determine 1) if the position location of both vehicles was known 2) if the firing vehicle was using a weapon system capable of producing the MILES effect shown on the engaged vehicle (i.e., was it a system capable of killing a tank?). If these and certain other variables are within the parameters of the program, the system produced a "paired event". [Ref. 6]

In order for determination of position location, a range pulse was sent by the PUC in response to an interrogation by the RDMS. This pulse had to be received by three or more A units in order to triangulate the player's location.

IV. SCREENING OF NTC DATA

A. NTC DATA DESCRIPTION

1. Nature

The following points need to be understood when analyzing data collected from NTC. As seen in Chapter III, NTC missions are free play and conducted in a natural combat environment, with only minimal controls to ensure safety. Activities are not experimentally controlled, due to the Army training philosophy of fixing responsibility while underwriting honest mistakes of commission [Ref 8: p. 8]. Analysis of NTC data occurs after the mission is complete, which requires the use of retrospective or "post-battle" analysis. Military tactics is an art, not a science and the analysis of data resulting from tactics, is an art which requires logic and common sense in order to apply the appropriate statistical techniques.

2. Composition

Data from NTC battles conducted during FY 1987 and 1988 is stored at the Army Research Institute-Presidio of Monterey (ARI-POM), in the ARI-POM Combined Training Center (CTC) Archive. The categories of data are based on format and consist of video, audio, paper, and digital information. Common sense integration of all available data categories is essential for coherent analysis.

a. Video Data

All task force and brigade AARs, as well as many company and platoon AARs are stored on Army standard 3/4 inch video tape. The task force AAR includes; a graphic and narrative replay of the mission, the OPFOR commander's briefing of his mission, a scoreboard of battle kills, discussions on unit strengths and weaknesses, key personnel intentions and actions, and how to improve unit performance.

b. Audio Data

Two forty channel voice tapes of FM radio conversations among various levels of the task force and brigade are recorded and stored. Principle command and administrative nets are always recorded.

c. Paper Data

The most useful paper product at the archive is the written take home package. This package contains the most accurate information on task force start strengths and casualties for each mission in the form of killer-victim scoreboards. It also contains NTC observer controller descriptions of missions in terms of the seven battlefield operating systems. Other paper products include operations orders and overlays and related studies and reports.

d. Digital Data

The heart of the ARI-POM CTC Archive is the INGRES relational database, contained in a VAX 11/780 computer. The database is created from the digital data tapes produced at NTC. A separate database is created for each task force mission and a unique mission name (e.g., MA870712) is assigned. Each mission database consists of 19 separate tables. These tables contain data collected by the NTC instrumentation system on different aspects of each mission. The following descriptions from Briscoe and Baldwin [Ref. 9] concern the tables related to combat vehicle identification, location, and operational status, as well as combat vehicle engagement data.

(1) Player, Vehicle, and Weapon Code Table (PVWT). The Weapon Code Table defines a unique code for each weapon present on the battlefield. The

codes allow correlation of MILES codes, vehicle types, and weapons. The PVWT is static; it doesn't change from database to database.

TABLE 2. PVWT LISTING

pside	ptype	pveh	pmiles	pwpn
B	01	M60 A1/A3 Tank	12	105mm main gun
B	02	APC	24	M2 Machine Gun
B	03	APC	07	TOW
B	29	Bradley	07	TOW
O	01	Tank (T-72)	10	125mm main gun
O	02	BMP	-	non weapon
O	03	BMP	14	PKT (73mm)
O	04	BMP	03	Sagger

Element Name	Element Description	Units
PSIDE	Side Code O(pfor) or B(luefor)	1 Char
PTYPE	Player Type Code	2 Char
PVEH	Vehicle Description	15 Char
PMILES	MILES Weapon Code	2 Char
PWPN	Weapon Description	15 Char
PAMMO	Initial Ammunition Load (not used)	5 Char

(2) Player State Initialization Table (PSIT). This table describes the player list at the beginning of the mission. It includes all players; OPFOR, BLUEFOR, and WHITE (controller).

TABLE 3. PSIT LISTING

pid	lpn	side	inst	ptype	org	track	pstat
HQ1	32	O	I	3	TOC	T	1
HQ2	33	O	I	1	TOC	T	1

Element Name	Element Description	Units
PID	Player Identification (Bumper number)	3 Char
LPN	Unique Logical Player Number	3 Char
SIDE	B(lue), O(pfor), or W(hite)	1 Char
INST	I(nstrumented) or N(ot instrumented)	1 Char
PTYPE	Player Type Code (See PVWT Table)	2 Char
ORG	Next higher Line Unit	20 Char
TRACK	T(racked) or U(ntracked) by RDMS	1 Char

PSTAT	Player Status Code- 1: Operational 2: Combat Loss 3: OC Gun Kill 4: Accidental Kill 5: Admin Kill 6: Mechanically Down 7: Mobility Kill	1	Char

(3) Player State Update Table (PSUT). This table tracks changes to all players throughout the duration of the mission. Fields that are subject to update are SIDE, INST, PTYPE, ORG, TRACK and PSTAT.

TABLE 4. PSUT LISTING

time	pid	lpn	side	inst	ptype	org	track	pstat
05 Feb 88 03:11:25	433	128	O	I	3	3/3-001	T	2
05 Feb 88 03:11:27	C65	310	B	I	1	C/2-005	T	5

Element Name	Element Description	Units	
TIME	Date and Time of Update	20	Char
PID	Player Identification (Bumper number)	3	Char
LPN	Unique Logical Player Number	3	Char
SIDE	B(lue), O(pfor), or W(hite)	1	Char
INST	I(nstrumented) or N(ot instrumented)	1	Char
PTYPE	Player Type Code (See PVWT Table)	2	Char
ORG	Next higher Line Unit	20	Char
TRACK	T(racked) or U(ntracked) by RDMS	1	Char
PSTAT	Player Status Code (See PSIT Description)	1	Char

(4) Pairing Event Table (PET). The Pairing table will maintain a time-ordered record of MILES events. It will also contain information relating to the firer if it is a legitimate pairing event.

TABLE 5. PET LISTING

time	tpid	tlpn	result	fpid	flpn	fwpn	frat	t_x	t_y	f_x	f_y
05 Feb 88 03:12:41	433	128	K		0	0	N	36250	96538		
05 Feb 88 03:13:42	C32	310	K		0	0	N	36225	96652		

Element Name	Element Description	Units	
TIME	Date and Time of Update	20	Char
TPID	Player Identification (Bumper number)	3	Char

TLPN	Unique Logical Player Number	3 Char
RESULT	N(ear miss), H(it), K(ill)	1 Char
FPID	Firer ID (Bumper Number)	3 Char
FLPN	Firer LPN	3 Char
FWPN	Firer Weapon Type (MILES - See PVWT)	2 Char
FRAT	Fratricide Indicator (Y/N)	1 Char
TX	Target position location X coordinate	5 Char
TY	Target position location Y coordinate	5 Char
FX	Firer position location X coordinate	5 Char
FY	Firer position location Y coordinate	5 Char

(4) Ground Player Location Table (GPLT). This table will maintain a time-ordered record of player location (PL) coordinates for each instrumented ground player. PL will be recorded at an operator-selected interval.

TABLE 6. GPLT LISTING

time	plpid	pllpn	x	y
05 Feb 88 03:14:26	111	38	36275	96588
05 Feb 88 03:14:26	112	39	36263	96600

Element Name	Element Description	Units
TIME	Date and Time of PL	20 Char
PLPID	Player Identification (Bumper number)	3 Char
PLLPN	Unique Logical Player Number	3 Char
X	Position location X coordinate	5 Char
Y	Position location Y coordinate	5 Char

3. Completeness and Accuracy

When analyzing the above data, it is necessary to understand problems with its completeness and accuracy. These problems are a result of the collection equipment and methods used during FY 1987 and 1988, which are discussed in Chapter III, Section E. Each of the above tables will be addressed. Even though the below problems identified in Shadell [Ref. 6] existed, careful integration of all available data will still give a relatively good representation of certain aspects of NTC battles.

a. PVWT and PSIT

The problem with these pre-battle tables deals with completeness. These tables of fully instrumented players do not include all vehicles and weapon systems on the battlefield. Only approximately 400 complete Player Unit Components (PUCs) were available during this period. In most battles, all armored tank killing systems (tank and vehicle-mounted anti-tank missiles) had the PUC, while ground-mounted TOWs, DRAGONs, and small arms just had MILES. These ground-mounted systems had MILES weapon effects, but their position location and engagement events could not be recorded.

b. PSUT and PET

Different types of kill events are recorded on the PSUT and PET. The PSUT lists changes in player status code (PSTAT) from a "1" (operational) to a; "2" (combat loss), "3" (OC god gun kill), "4" (accidental kill), or "5" (administrative kill). A PSTAT of "2" would result from a MILES kill. The "3" and "5" kills usually resulted from indirect or minefield casualty assessments and sometimes from an administrative kill of a faulty MILES during the battle. The PET lists transmitted MILES kills as a "K". Both tables have to be cross-checked to obtain the most accurate kill event data.

MILES events did not get recorded on the PET and PSUT tables if the PUC was not transmitting, or the transmission was not relayed by an A unit due to terrain line of sight. Multiple kill transmissions from the same vehicle were sometimes recorded on the PET table due to faulty PUC components and occasionally due to boresighting of that vehicle's MILES before or after the actual battle. In order for the time coincidence pairing algorithm to work; both the firing and engaged weapon systems had to have a working PUC, the MILES events had to be transmitted to the CIS, and both position locations had to be known. These paired events were at most 20 percent of recorded engagements on the PET table.

Even though the PSUT and PET contain kill events that occur during a mission, the most accurate summary of kills is found in the written take home package. These take home packages contain killer-victim scoreboards that were produced by NTC observer controllers.

c. *GPLT*

Gaps in GPLT player locations occurred if terrain prevented reception of a PUC range pulse by three A units. The time interval between player location updates in this table is selected when the database is created at ARI-POM and is typically 5 or 10 minutes. This keeps a mission's GPLT length down to approximately 20,000 rows, but sacrifices accuracy.

B. GROUND MANEUVER FORCE

For the purposes of this analysis, the term "ground maneuver force" refers to armored tank killing systems. Specifically, BLUEFOR M1 Abrams and M60 series tanks, Improved TOW Vehicles (ITVs), and M2/M3 Bradley Fighting Vehicles (IFVs/CFVs) are considered. On the OPFOR side, VISMOD T-72 tanks and BMPs are considered. The terms "ground maneuver force", "force", or "vehicle" in the analysis refer to the above defined tank killing systems.

C. KILL EVENT DATA SCREENING

In order to analyze kill events of just armored tank killing systems, and because of the above accuracy problems with the kill event data in the PET and PSUT, the data needed to be screened. This kill event screening process was accomplished on the archive's VAX 11/780 computer with the FORTRAN/EQUEL program listed in

Appendix A. The program tailors the kill data and increases its accuracy in the following ways:

- Only BLUEFOR tank and mounted TOW system kills, and OPFOR T-72 and BMP kills are considered. This corresponds to the definition of "ground maneuver force" in Section B above.
- Kill events occur before and after the battle due to reasons such as boresighting MILES. Actual start and change of mission times were obtained from the NTC Observation Division, Center for Army Lessons Learned, and kill events are only recorded during this actual mission time period.
- A vehicle is permanently killed after it is first killed in the PET table or it receives a PSTAT in the PSUT table of "2" (combat loss), "3" (OC gun kill), or "5" (administrative kill). A PSTAT code "3" (accidental kill) is not considered a valid kill. Valid re-keying of MILES during the battle is not identified in the program and is a source of error. However, bringing a killed player back to life is a relatively rare event in most battles.
- The kill events in the PSUT table do not list an associated location. Therefore, the program searches the GPLT to find the vehicle's location within one GPLT time increment of the kill time in the PSUT.

Table 7 shows screened kill event data output from this program. Kill times are listed in both decimal time (in terms of a 24 hour clock) and integer time (72610 is 7:26:10 hours). If a kill event is obtained from the PET, a "K" is shown under Code/Result and a fratricide indicator (Y/N) is listed. If the kill event is obtained from the PSUT, the appropriate PSTAT code is listed under Code/Result.

TABLE 7. SCREENED KILL EVENT TABLE (SKET) LISTING

Dec. Time	Int. Time	LPN	Side	Type	Description	PID	Code/ Result	Frat	X	Y
7.4361	72610	140	O	2	BMP	531	2		37400	95738
7.4461	72646	323	B	1	M60 A1/A3 Tank	12A	5		46838	96038
7.7864	74711	234	O	1	Tank (T-72)	D24	K	N	39650	94613
7.8836	75301	365	B	1	M60 A1/A3 Tank	32B	2		44250	93350
7.9436	75637	327	B	1	M60 A1/A3 Tank	22A	K	N	38275	94063

D. GROUND VEHICLE POSITION LOCATION DATA SCREENING

The locations of live armored tank killing systems at a critical time in the battle was the other table that needed to be derived. This data also required a screening process accomplished in the form of the FORTRAN/EQUEL program listed in Appendix B. The following techniques are used in this program:

- Only armored tank killing system locations are listed.
- The input critical time is compared to the interval times in the GPLT. This critical time is bracketed on both sides by GPLT times and then a linear interpolation of both the X and Y grid coordinates is calculated, based on time interval ratios. This provides a more accurate vehicle location at this critical time, instead of just using the closest interval time in the GPLT.
- Each vehicle is compared to the Screened Kill Event Table to determine whether it is alive or killed at the input critical time.

Table 8 shows the screened vehicle location output from this program. The event time is listed in decimal and integer form, as in the SKET above. The Status column indicates "L" for live or lists one of the kill codes from the SKET.

TABLE 8. SCREENED GROUND VEHICLE POSITION LOCATION TABLE (SGPLT) LISTING

Dec. Time	Int. Time	LPN	Side	Type	Description	PID	Status	X	Y
8.2417	81430	36	O	3	BMP	HQ1	L	30125.0	102950.0
8.2417	81430	37	O	1	Tank (T-72)	HQ2	K	29550.0	102663.0
8.2417	81430	38	O	3	BMP	HQ5	L	29563.0	102725.0
8.2417	81430	39	O	3	BMP	HQ6	L	29263.0	116863.0
8.2417	81430	41	O	3	BMP	110	L	4875.0	86375.0

V. TASK FORCE DELIBERATE ATTACK OPERATIONS

A. NTC MISSION SCENARIO DEVELOPMENT

The types of missions, such as deliberate attack, conducted by a unit at NTC are developed by the commander of the task force's parent brigade in conjunction with NTC personnel. Once the mission list is finalized, NTC personnel create the mission scenarios. Unique mission scenarios are developed for each NTC rotation. There are no "standard" or "canned" missions that task forces are given. There will be certain similarities between missions, due to only a certain amount of key terrain in the central and southern corridors. The same terrain has been contested in numerous rotations, but there is always some factor which makes a mission scenario significantly different from other missions conducted in that area. [Ref. 6]

B. FUNDAMENTALS

Deliberate attack and defense in sector are the two most frequent missions conducted at NTC. The deliberate attack mission, by its very nature, uses maneuver more than the defense in sector mission, and is an obvious choice for a maneuver analysis. Most deliberate attack mission statements at NTC contain the directive to seize a designated objective area. The following definitions are helpful in understanding NTC deliberate attacks:

> Deliberate Attack: an attack planned and carefully coordinated with all concerned elements based on thorough reconnaissance, evaluation of all available intelligence and relative combat strength, analysis of various courses of action, and other factors affecting the situation. It generally is conducted against a well-organized defense. [Ref. 5: p. 1-8]

Most NTC deliberate attack missions include the directive to seize a piece of terrain, and the following further clarifies this concept:

> Seize: to "clear" a designated area and "obtain control" of it.
>
> Clear: to eliminate organized resistance in an assigned area by destroying, capturing, or forcing the withdrawal of enemy forces that could interfere with the unit's ability to accomplish its mission.
>
> Obtain Control (Secure): to gain possession of a position or terrain feature, with or without force, and to deploy in a manner which prevents its destruction or loss to enemy action. [Ref. 5]

C. OPFOR DEFENSIVE DOCTRINE

The Opposing Force (OPFOR) at NTC is designed to replicate threat defensive tactics. During the FY 1987 and 1988 time period, units conducting deliberate attack missions at NTC may have faced either an independent OPFOR company or an OPFOR battalion. When faced with an OPFOR battalion, the task force was to locate and attack one of its weak OPFOR companies. The deliberate attack task force objective at NTC was placed in the vicinity of an OPFOR company defensive position. Figure 8 focuses in on a typical threat company defensive position. The position doctrinally covers a frontage of 1500 to 2000 meters. Obstacles are planned and executed in three belts, with the approximate ranges of 1500, 1000, and 400 meters. Even though threat direct fire weapons ranges extend to 4000 meters, the planned OPFOR kill zone is from 1500 meters to 400 meters to obtain surprise and shock.

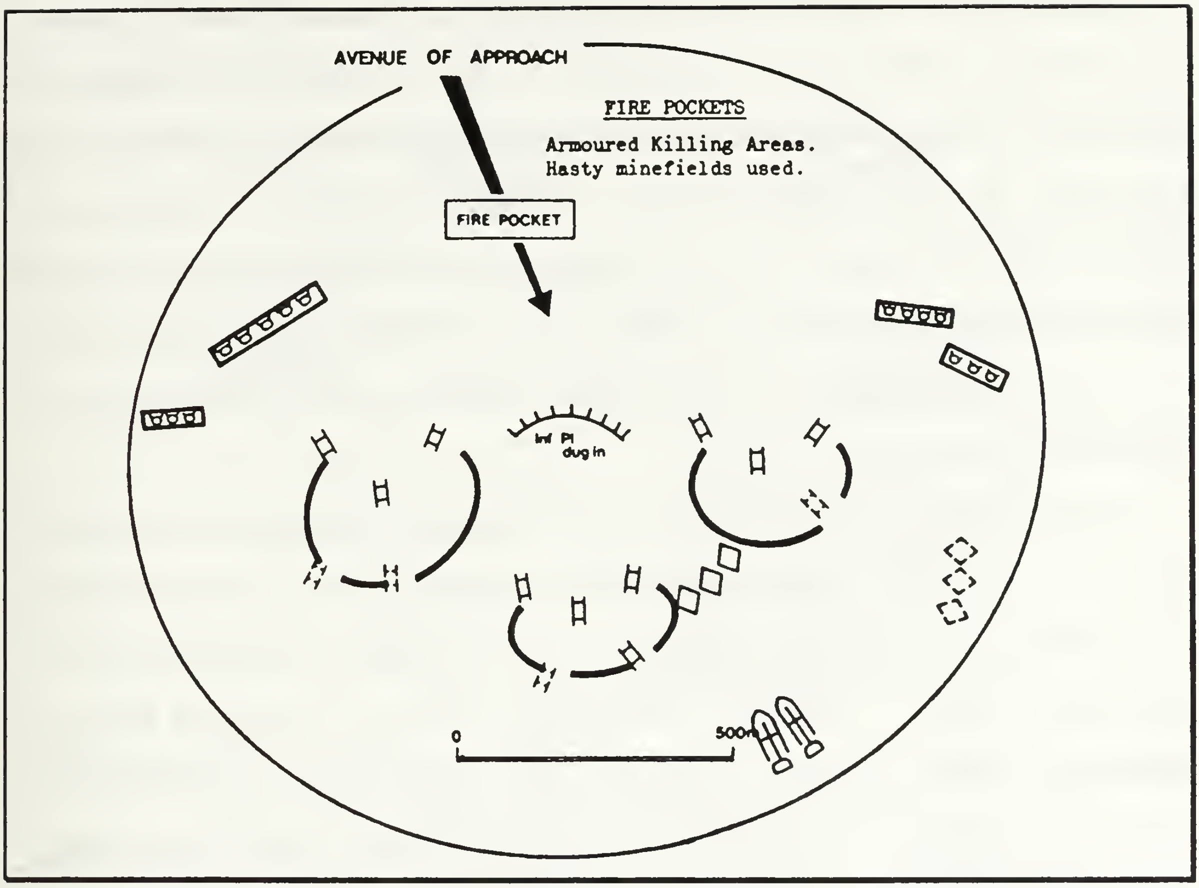

Figure 8. Independent Motorized Rifle Company in the Defense

D. CONDUCTING THE DELIBERATE ATTACK

After the task force receives a deliberate attack mission, planning begins. Reconnaissance should start immediately and continue throughout the mission. Information about the terrain and enemy disposition is crucial to planning the attack. The task force is usually organized into a breaching force, an assault force, and a support force. A company-sized reserve should be retained and can be initially located in the support force. The task force commander plans his scheme of maneuver to avoid striking the enemy main strength. The techniques of deception, surprise, and an indirect approach to strike the enemy's flank and rear should be used.

Execution of the attack is divided into four phases. The task force will; close on the objective, isolate the penetration site, breach or bypass, and exploit the penetration. During all phases, task force units should deploy, maneuver, and synchronize in order to provide mutual fire support. During the "close on the objective" phase, the task force uses available terrain or limited visibility to avoid enemy detection and maneuver to a position of advantage near the objective. The commander can enhance the above natural avoidance assets with smoke, fire suppression, and speed.

In the "isolate the penetration site" phase, the weakest enemy platoon position needs to be isolated by suppressing adjacent enemy positions with smoke and indirect fores. Overwhelming combat power is massed at the penetration site. During the "breach or bypass" phase, shown in Figure 9, obstacle belts are penetrated by either breach or preferably bypass. The breach is conducted by the breaching force, usually formed around a mechanized infantry team and mutually supported by the other task force elements.

In the "exploit the penetration" phase, the assault force passes rapidly through the breach on a narrow front, becoming the task force main effort, as shown in Figure 10. The assault force maneuvers and masses its fires to overwhelm and destroy enemy platoons in detail. An envelopment maneuver, seen in Figure 10, is preferred. The other task force elements mutually support the assault force and isolate remaining enemy platoons. The reserve should be prepared for commitment during this phase. Once the objective is seized (control obtained and cleared of enemy forces), the task force consolidates and reorganizes or continues the attack. The objectives of NTC deliberate attacks are the doctrinal objectives of destroying forces and seizing terrain, while preserving friendly forces for follow-on missions. [Ref. 4: p. 3-2]

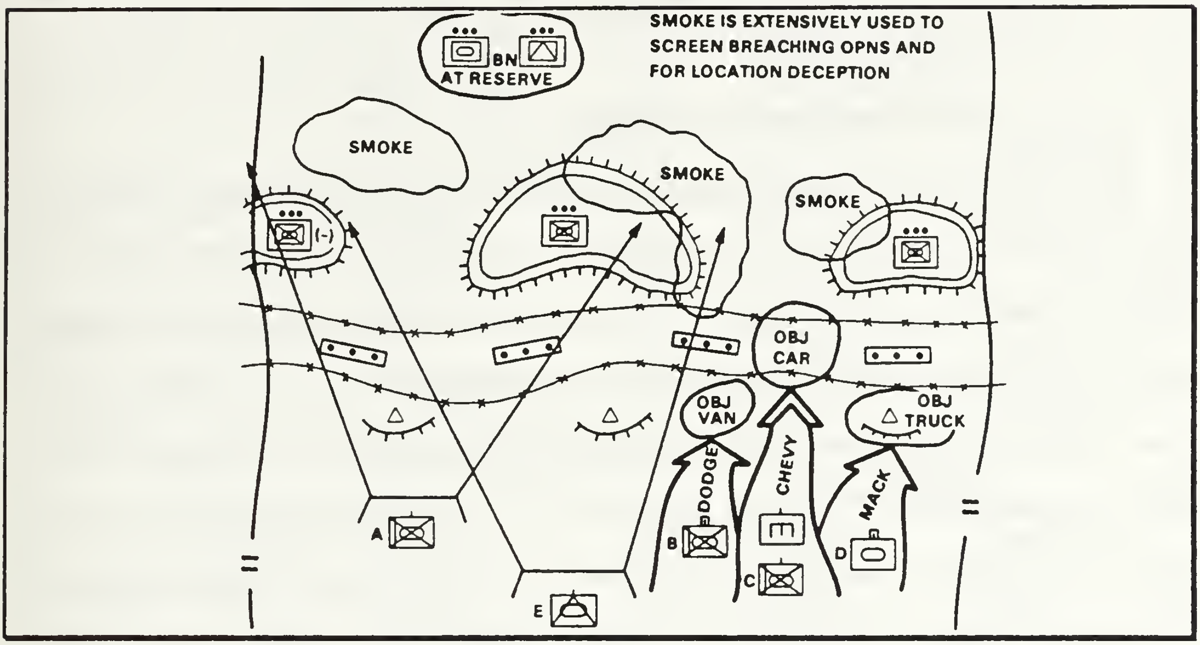

Figure 9. Attack of a Strongpoint - The Breach

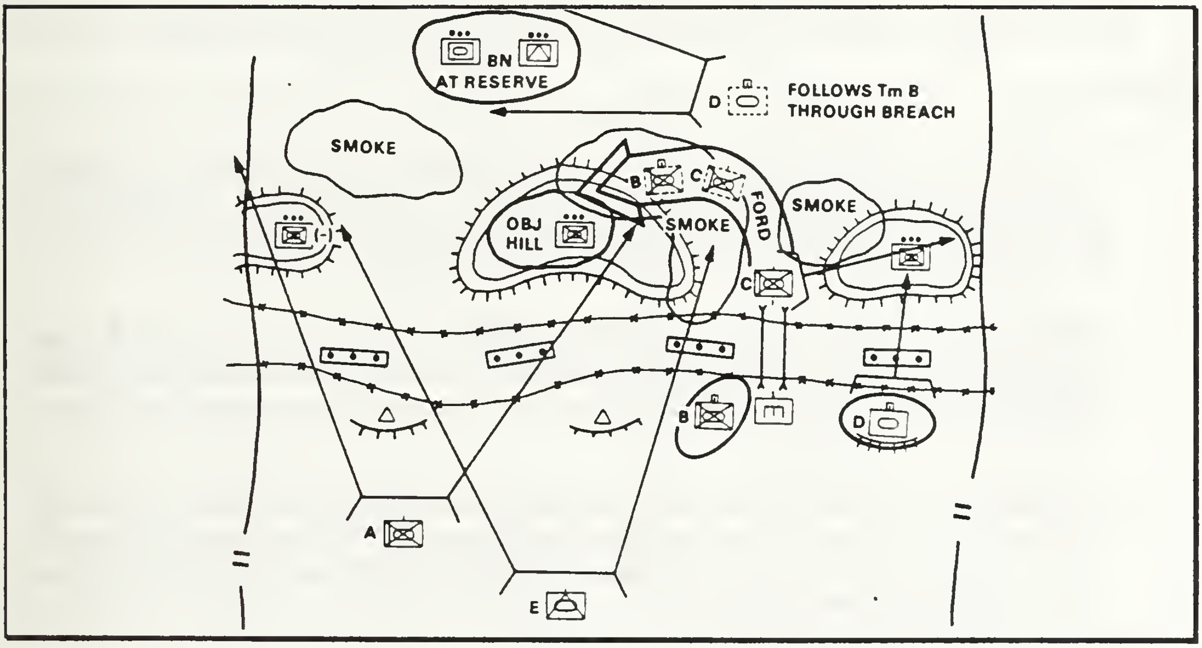

Figure 10. Attack of a Strongpoint - Exploit the Penetration

VI. DELIBERATE ATTACK MISSION SIZE AND MEASURE OF EFFECTIVENESS

A. BATTLE SIZE DETERMINATION

Continental-based United States heavy task forces usually train at NTC once every two years (see Chapter 3, Section C). A two year period (FY 1987 and 1988) was initially used as the basis to select deliberate attack missions, due to heavy task forces training at NTC at least once during this time. Due to data collection time constraints, this time period was slightly reduced to include all 14 rotations of FY 1987 (rotations 8701-8714) and 10 rotations of FY 1988 (rotations 8701-8710). Missions categorized as night attacks, hasty attacks, or counterattacks were not included. The population size of 41 deliberate attack missions from rotations 8701-8810 is shown in the first column of Table 9.

Upon further analysis of these 41 missions, three accuracy problems were identified:

- Missions conducted in the Nelson Lake training area generated extremely inaccurate data in the Ground Player Location Table (GPLT). This was due to the extremely broken terrain in these areas, which interfered with PUC line of sight radio transmissions to at least three A units.

- Some missions were stored at the ARI-POM CTC Archive with a GPLT time interval of 10 minutes (600 seconds) rather than the standard 5 minute (300 second) interval. This 10 minute interval reduced the accuracy of these missions' position data.

- Modernized task forces included partially instrumented Infantry Fighting Vehicles (IFVs) and Cavalry Fighting Vehicles (CFVs). Kills of these vehicles were recorded in the database, but their locations during the mission were not recorded in the GPLT.

TABLE 9. SCREENED BLUEFOR DELIBERATE ATTACK MISSION LIST

Mission	Date	NTC Location	GPLT Int. (secs)	Task Force Type	Screened Missions
AA870104	861008	***NELSON LAKE***	300	***Mod(IFV/CFV)***	
MA870106	861008	***NELSON LAKE***	300	***Mod(IFV/CFV)***	
AA870113	861013	NORTH LANGFORD LK	300	***Mod(IFV/CFV)***	
MA870212	861106	LANGFORD WELL LAKE	300	Non Mod	MA870212
MA870220	861108	HILL 909 SOUTH	300	Non Mod	MA870220
AA870220	861110	WHALE GAP	300	Non Mod	AA870220
AB870301	861125	RED LAKE PASS	300	Non Mod	AB870301
AB870305	861128	AUSTRALIA	***600***	Non Mod	
MA870317	861201	WHALE GAP	300	Non Mod	MA870317
MA870319	861202	SIBERIA	300	Non Mod	MA870319
MA870404	870110	***NELSON LAKE***	300	Non Mod	
AA870432	870122	HILL 909 SOUTH	300	Non Mod	AA870432
AA870503	870203	CENTRAL CORRIDOR	***600***	***Mod(IFV/CFV)***	
AA870512	870206	LANGFORD WELL LAKE	300	***Mod(IFV/CFV)***	
AA870513	870207	AUSTRALIA	***600***	***Mod(IFV/CFV)***	
MA870604	870226	AUSTRALIA	300	Non Mod	MA870604
AA870614	870303	AUSTRALIA	***600***	Non Mod	
AA870616	870304	AUSTRALIA	***600***	Non Mod	
MA870626	870308	GRANITE PASS	300	Non Mod	MA870626
AA870721	870331	RED LAKE PASS	300	***Mod(IFV/CFV)***	
AA870734	870404	HILL 909 NORTH	300	***Mod(IFV/CFV)***	
MA870806	870417	CENTRAL CORRIDOR	300	Non Mod	MA870806
AA870815	870421	***AUSTRALIA (No Blue PL)***	300	Non Mod	
MA870828	870428	HILL 909 NORTH	300	Non Mod	MA870828
AA871115	870716	LANGFORD WELL LAKE	300	High/Low	AA871115
MA871233	870817	RED LAKE PASS	300	Non Mod	MA871233
MA871308	870830	HILL 909 SOUTH	300	Non Mod	MA871308
AA871325	870909	***NELSON LAKE***	300	Non Mod	
MA871409	870922	NORTH LANGFORD LK	300	Non Mod	MA871409
AA871421	870929	WHALE GAP	300	Non Mod	AA871421
MA880212	871113	LANGFORD LAKE	300	Non Mod	MA880212
MA880220	871117	CENTRAL CORRIDOR	300	Non Mod	MA880220
AA880324	871209	TV HILL(VIC HILL 909)	300	Non Mod	AA880324
MA880422	880119	SIBERIA	300	High/Low	MA880422
MB880511	880207	HILL 909	300	***Mod(IFV/CFV)***	
AA880614	880304	LANGFORD LAKE	300	Non Mod	AA880614
AA880627	880308	CENTRAL CORRIDOR	300	Non Mod	AA880627
MA880632	880308	BROWN-DEBNAM	300	Non Mod	MA880632
AA880634	880309	***NELSON LAKE***	300	Non Mod	
MA880730	880402	CENTRAL CORRIDOR	300	***Mod(IFV/CFV)***	
MA881053	880614	VIC HILL 720	300	Non Mod	MA881053

These accuracy problems are highlighted in the third, fourth, and fifth columns of Table 9. The screened population of accurate deliberate attack missions from rotations 8701-8810 is shown in the last column of Table 9. These 24 screened missions constitute the population size of accurate BLUEFOR deliberate attacks used in the analysis.

The OPFOR also conducts replicated Soviet attacks when BLUEFOR task forces are assigned a defense in sector (DIS) mission. BG Funk, during a briefing on this thesis, 21 July 1989, emphasized the proficiency of the OPFOR in massing its forces at critical places and times during OPFOR attacks. A separate analysis of OPFOR attacks during BLUEFOR defense in sector missions is conducted, applying the same methodology used in the BLUEFOR deliberate attack missions (see Chapter VII and VIII). BLUEFOR defense in sector missions from rotations 8701-8810 were first screened for the three accuracy problems listed above. There was a population of 48 available screened DIS missions available to analyze. Due to time constraints, six OPFOR attacks (listed in Table 10) were randomly selected from these screened missions. These six missions constitute the sample size of accurate OPFOR attacks used in the analysis.

B. DELIBERATE ATTACK MEASURE OF EFFECTIVENESS

1. Considerations

The concept of deliberate attack mission effectiveness has to be clearly defined and then quantified in order to compare mission performances. Initially, the Department of the Army's Mission Training Plan for the Tank and Mechanized Infantry Battalion Task Force (ARTEP 71-2-MTP) was reviewed. The purpose of this MTP is to define mission standards for the battalion task force. However, when checking the maneuver tasks listed in this MTP, the deliberate attack mission is not covered. An attack or counterattack by fire mission is listed, but the conditions clearly state "the intent is not to close with and overrun the enemy position." An assault mission is also listed, but the conditions state "the enemy motorized rifle company is in a hasty defense." Neither of these missions are a deliberate attack as described in FM 71-2 [Ref. 4]. It is interesting to note that quantified task standards of offensive missions in the MTP consist of percent enemy casualties and percent friendly survivors. This could serve as a guide to a deliberate attack mission measure of effectiveness. [Ref. 10]

TABLE 10. SCREENED OPFOR ATTACK MISSION LIST

Mission	Date	NTC Location	GPLT Interval (secs)	Task Force Type
AA870225	861112	SIBERIA	300	Non Mod
MA871312	870901	SIBERIA	300	Non Mod
AA880212	871111	SIBERIA	300	Non Mod
AA880320	871208	LANGFORD WELL LAKE	300	Non Mod
MA880415	880116	HILL 909	300	High/Low
MA880618	880302	CENTRAL CORRIDOR	300	Non Mod

2. Description

The framework of the selected deliberate attack measure of effectiveness is based on doctrinal factors that must be considered in tactical mission planning. These factors are; mission, enemy, terrain, troops and time available (METT-T). Each factor is discussed below in terms of NTC deliberate attack missions:

- Mission: All missions are daytime deliberate attacks.
- Enemy: A primary objective of the deliberate attack is the destruction of enemy forces. This destruction can be quantified in terms of percent enemy ground maneuver forces destroyed in combat during each mission.
- Terrain: NTC deliberate attacks typically include the mission to seize a piece of terrain called an objective. There are no doctrinal guidelines which quantify the concept of seizing an objective. A subjective assessment can be made of whether the unit seized the objective for each mission, but there is not an accepted quantitative methodology for making this determination. One

concept is to use a percentage to measure a unit's performance in seizing an objective, based on its vehicle locations at end of mission. A follow-on BDM study to Root and Zimmerman [Ref. 7], will explore this technique. Upon validation of this study, a percentage measure for seizing terrain could be incorporated with the "enemy" and "troops available" percentage measures described in this section. For the purposes of this analysis, a terrain measure was not included, since it is not currently quantified.

- Troops Available: Another primary objective of the deliberate attack is the survival of friendly forces for follow-on missions. This survival can be quantified in terms of percent friendly ground maneuver forces surviving each mission.

- Time Available: Since NTC missions are scenario-driven, mission planning and preparation time available for NTC deliberate attack missions is relatively constant at approximately 20 hours. This factor is expected to uniformly affect each mission and is not considered in the MOE.

The selected deliberate attack MOE is shown in Figure 11. It is based on the attrition of ground maneuver forces and includes the quantifiable mission objectives of enemy force destruction and friendly force survival. These two measures can be weighted by the commander using an α value between zero and one. In this analysis, α was set at .5 in order to equally weight the two objectives. Future deliberate attack MOEs can possibly include a third mission objective dealing with terrain.

3. MOE Results for Selected Battles

BLUEFOR and OPFOR deliberate attack MOE results for the selected missions are listed in Table 11 in rank order. The BLUEFOR and OPFOR attrition data used in this MOE came from each mission's take home packet (see Chapter III, Section 2). This is the most accurate summary attrition data available, since it was collected by NTC observer controllers during each mission. The histograms in Figure 12 are shown to get a general idea of the range and distribution of the MOE for the selected BLUEFOR and OPFOR missions.

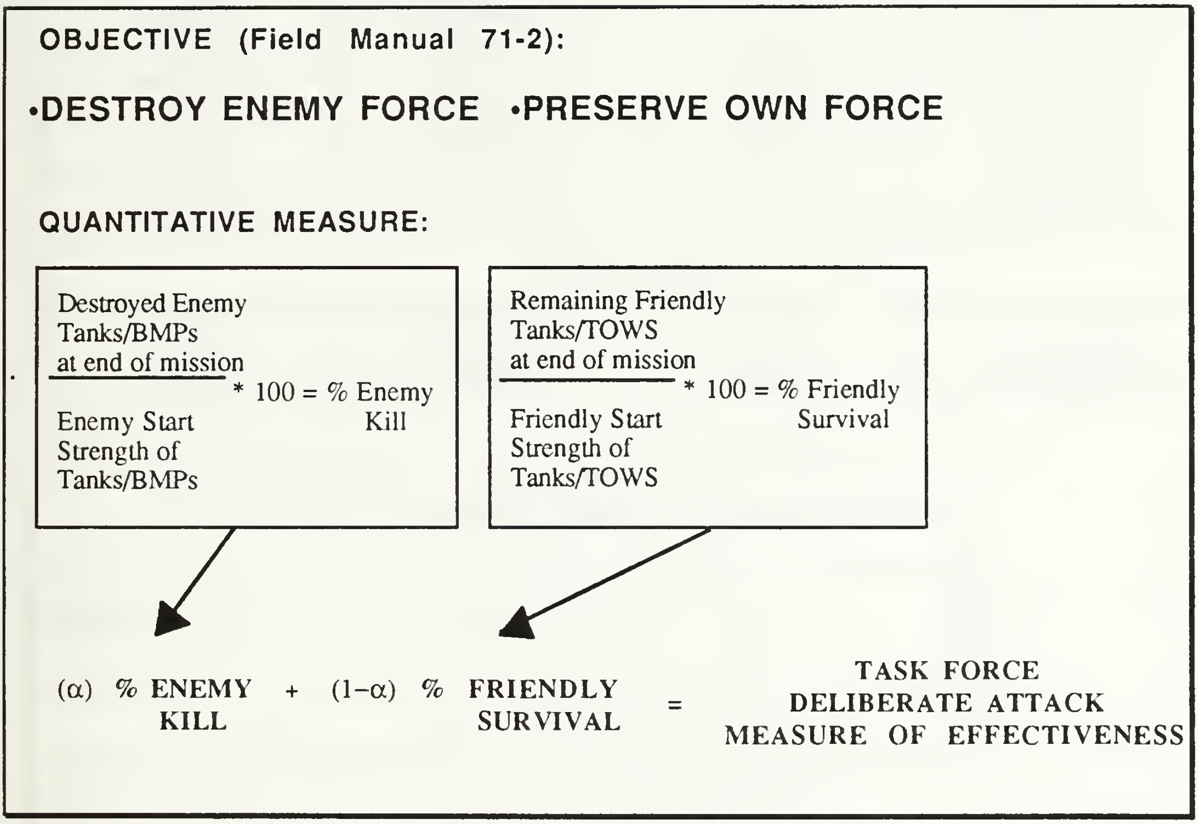

Figure 11. Deliberate Attack Mission Measure of Effectiveness (MOE)

TABLE 11. BLUEFOR AND OPFOR DELIBERATE ATTACK MOE LISTING

BLUEFOR DELIBERATE ATTACKS			
Mission (Ranked by MOE)	MOE (%)	Mission (Ranked by MOE)	MOE (%)
MA880632	70.238	MA870317	45.676
MA870212	67.160	MA880220	43.954
MA870626	66.667	AA870432	38.616
MA870220	66.165	MA880422	35.253
AA870220	65.126	MA870828	32.677
MA871409	59.790	AA880614	32.064
MA870319	59.524	MA870806	30.401
MA871233	58.081	AA871115	29.688
AA871421	57.986	AB870301	26.331
MA881053	57.895	AA880324	25.521
AA880627	55.556	MA880212	24.313
MA870604	51.470	MA871308	18.295
OPFOR ATTACKS			
MA880415	80.410	MA871312	63.104
AA880320	72.619	AA870225	53.187
AA880212	68.086	MA880618	48.554

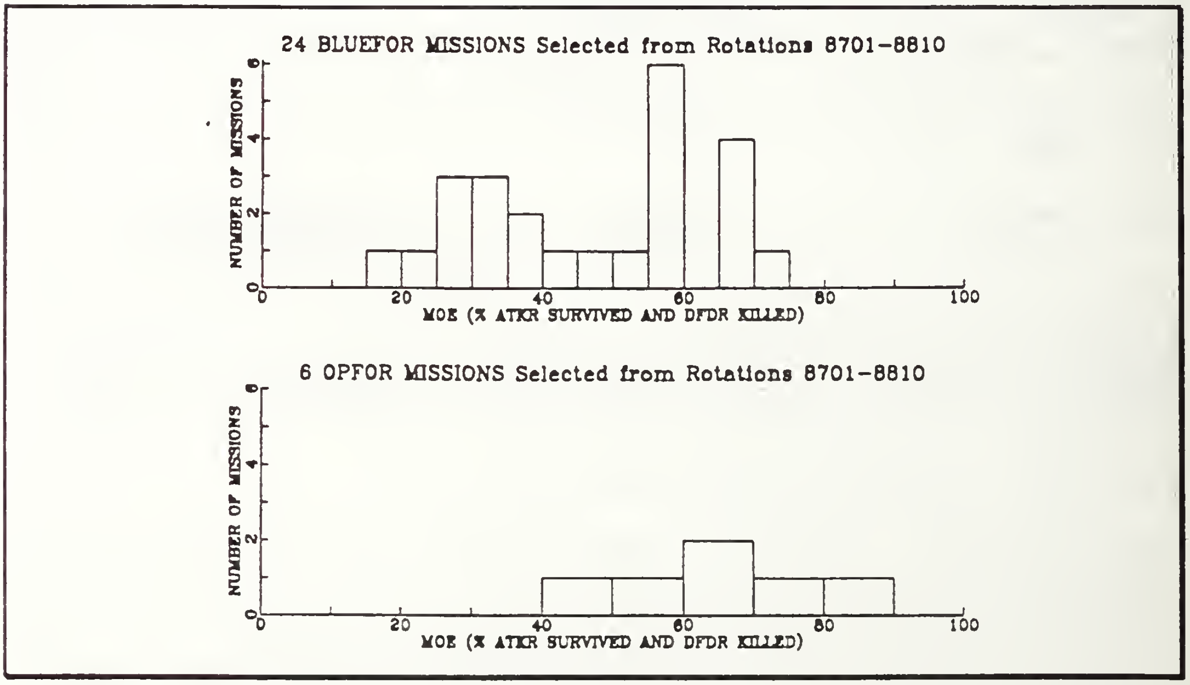

Figure 12. BLUEFOR and OPFOR Deliberate Attack MOE Results

VII. CONCENTRATION OF GROUND MANEUVER FORCES AT THE BATTLE POINT OF CRITICAL ATTRITION

A. DETERMINATION OF THE BATTLE POINT OF CRITICAL GROUND FORCE ATTRITION

In order to focus each deliberate attack mission, based on attrition data of the ground maneuver forces, the battle point of critical ground force attrition was defined and quantified using graphical and analytic data analysis. A battle point was further defined as an area and time during a respective mission. The critical ground force attrition area was first obtained and then, using this area, the critical ground force attrition time was derived. This critical ground force attrition time was then used to measure live vehicle ground force concentration. A sample BLUEFOR deliberate attack mission (MA870212) is used to describe this methodology.

1. Deliberate Attack MA870212 Mission Description

A brief mission description and narrative summary of execution for BLUEFOR deliberate attack MA870212 follows. The battle took place in the OP2 training area. The initial maneuver graphics are depicted in Figure 13, along with the general terrain features. The task force was to conduct a deliberate attack at 0630 hours to seize the task force objective (NK 4095) and, on order, continue the attack. The task force task organization consisted of two armor heavy teams, two mechanized infantry heavy teams and a pure antitank company. The initial commander's concept was to close on the objective in a task force "V" formation, with three teams forward and one team and the antitank company in support. The three forward teams each had specific objectives to seize in the vicinity of the task force objective, with the reserve team and antitank company providing a base of fire.

After these objectives were taken, the task force would consolidate, reorganize, and on order, continue the attack. No task force penetration site was specified and teams were to individually breach or bypass obstacles.

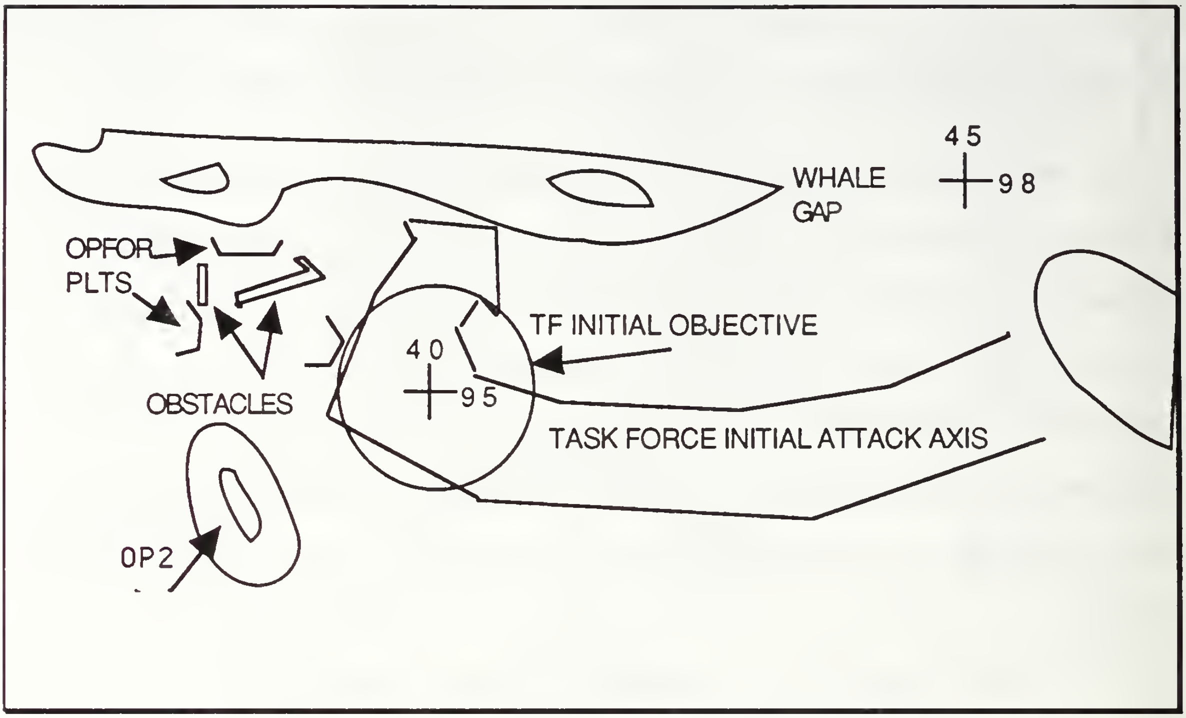

Figure 13. BLUEFOR Deliberate Attack MA870212 Initial Maneuver Graphics

Before the mission start time of 0630 hours, the task force scouts established that there was no enemy on the task force objective. Also, the scouts established the location of enemy motorized rifle platoons, denoted on Figure 13. This caused the task force commander to change his concept at 0530 hours. The objective was changed to coincide with the actual enemy locations. The task force was to attack in an "H" formation with two teams forward. During actual execution, the main attack came from the south at 0805 hours, with a supporting attack from the east. These two attacks effectively engaged the defending motorized rifle company (MRC) and by 0823 hours, three teams were moving behind the MRC position. At 0855 hours, the antitank company had moved forward to engage the MRC and by 1000 hours, the task force had destroyed the MRC and received a change of mission.

The deliberate attack MOE for mission MA870212 is 67.16 %, which is one of the better BLUEFOR MOE scores. The task force scouts performed well in locating and reporting enemy positions, without being killed. The task force did not plan for or conduct an isolation or exploitation of a task force penetration site and therefore, it was more difficult to isolate the enemy platoons and focus task force combat power. The task force did not have to conduct extensive breaching operations. The task force was able to defeat the enemy due to the maneuver of individual teams, aggressive infantry, and a few effective tanks. [Ref. 11]

2. Critical Ground Force Attrition Area

For this mission, the screened BLUEFOR and OPFOR kill locations from the Screened Kill Event Table (SKET) formed a scatter plot of points with grid coordinates represented by the X and Y axes, as seen in Figure 14. All plots were done in GRAFSTAT, which is a graphics program based on the computer language APL (A Programming Language).

It was difficult to isolate critical attrition areas, unless enhancement was done to this graph. First, a bivariate empirical density surface was plotted, as shown in Figure 15. This plot is explained below:

> This function generates a bivariate empirical density of the X and Y variable entries and plots the density surface (over a rectangular (x, y) grid). The empirical density is a surface that integrates to one. A cosine bell with an area inversely proportional to the total number of points is centered over each (X, Y) point. If X and Y are data values and x and y are any two (grid) coordinates, then the contribution to

the density estimate at (x, y) from the observation (X, Y) is proportional to

$$1+\cos\left(\left(\left(\frac{2(X-x)}{WX}\right)^{2}\right)+\left(\left(\frac{2(Y-y)}{WY}\right)^{2}\right)\right)^{1/2}$$

The WX and WY width entries used were the default entries given by the formula $\frac{\text{Xmax (orYmax) - Xmin (orYmin)}}{\text{N}}$, where N is chosen to give a total number of intervals that is somewhat larger than $1 + \log_2$(No. of (X, Y) pairs). A 20 by 20 resolution of the rectangular (x, y) grid was used in this methodology. [Ref. 12]

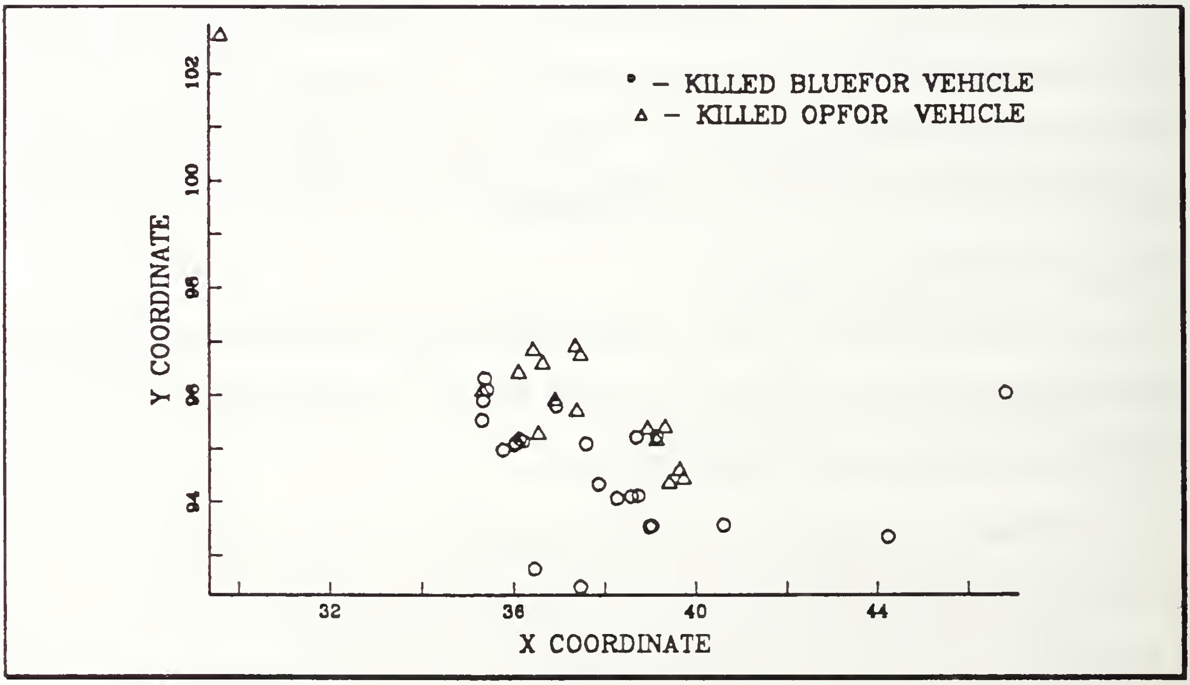

Figure 14. Deliberate Attack MA870212 Kill Locations

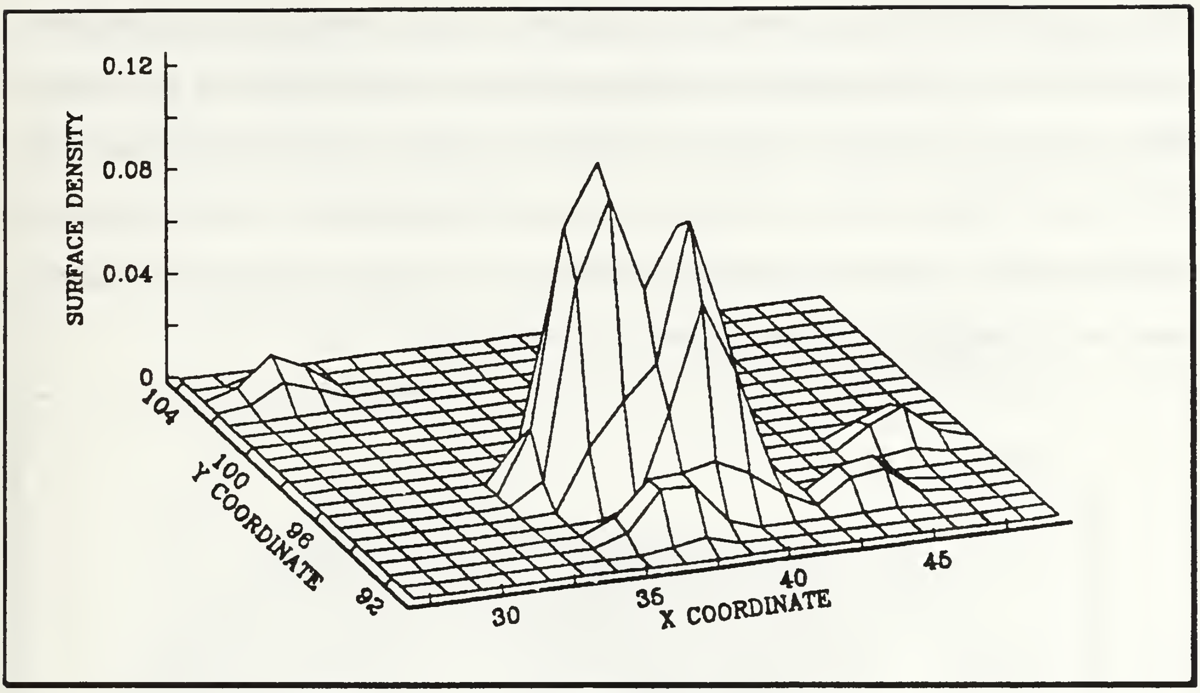

Figure 15. Deliberate Attack MA870212 Attrition Surface Density

The problem with the density plot in Figure 15 is a lack of differentiation between BLUEFOR and OPFOR attrition. The highest peak corresponds to the location with the greatest density of kills, but it is not known whether this attrition density was an even mix of both sides or a majority of BLUEFOR or OPFOR kills. This information is important, since an attrition area with the majority of kills from one side is more critical, and will have greater influence on the force ratio, than an attrition area with an even exchange of kills.

In order to incorporate the side of each killed vehicle, a relative surface density plot was created, as shown in Figure 16. This relative density was calculated exactly the same as the normal surface density plot in Figure 15, except at each OPFOR killed vehicle location, a raised cosine bell was placed and at each BLUEFOR killed vehicle location, a lowered cosine bell was placed, showing relative density of attrition locations, based on side. Positive surfaces (plain lines above the 0 plane) show a greater density of killed OPFOR vehicles when compared to BLUEFOR killed vehicles and negative surfaces (dashed lines below the 0 plane) show a greater density of killed BLUEFOR vehicles. The GRAFSTAT/APL function ∆154DEN, which calculates the normal bivariate surface density matrix was modified to calculate the matrix for the relative surface density plot. The original and modified ∆154DEN functions are listed in Appendix C.

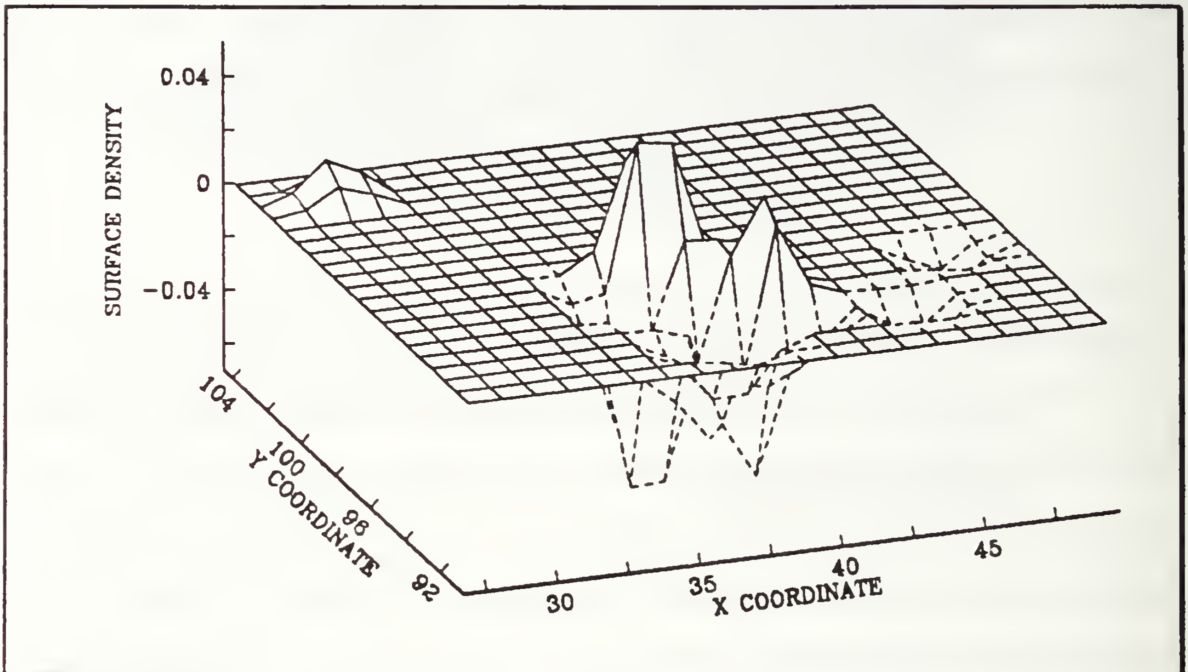

Figure 16. Deliberate Attack MA870212 Relative Attrition Surface Density

Another view of this same surface is shown with contour lines in Figure 17. The actual killed vehicle locations were superimposed on this contour plot to show the positive and negative influence of OPFOR and BLUEFOR kills, respectively. The highest peak and lowest depression were found and these two locations indicated the greatest relative attrition centers for that mission. Figure 18 is a magnification of the region containing these attrition centers. Circular regions were then drawn using as center the most extreme attrition peak and depression; both having a radius of 2000 meters. This radius is based on the estimate of a tank or TOW being decisively engaged within a range of 2000 meters under NTC conditions.

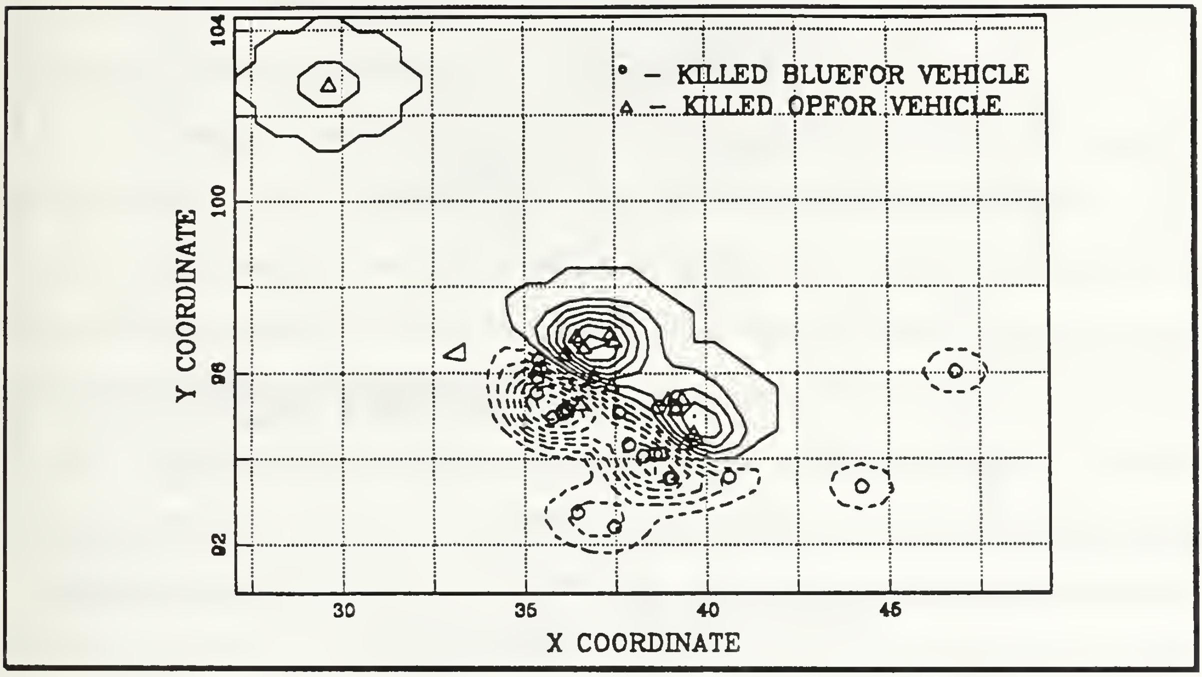

Figure 17. Deliberate Attack MA870212 Relative Attrition Surface Density Contour Plot

After examining the relative attrition density plots of all selected missions, two categories emerged. The first category, called an "even" battle, is represented by the above sample mission (MA870212). The relative density plot showed peaks and depressions, with the greatest peak and depression being relatively close (within 3000 meters). In these "even" battles, the intersection of the greatest peak and depression circles was used to shape and orient the critical attrition area. The second category, called an "OPFOR dominated" battle, is represented by a relative density plot of large depressions and, at most, a few small peaks. In these battles, there were not enough OPFOR killed to shape attrition areas. Therefore, the circle centered on the greatest depression was used as the critical attrition area.

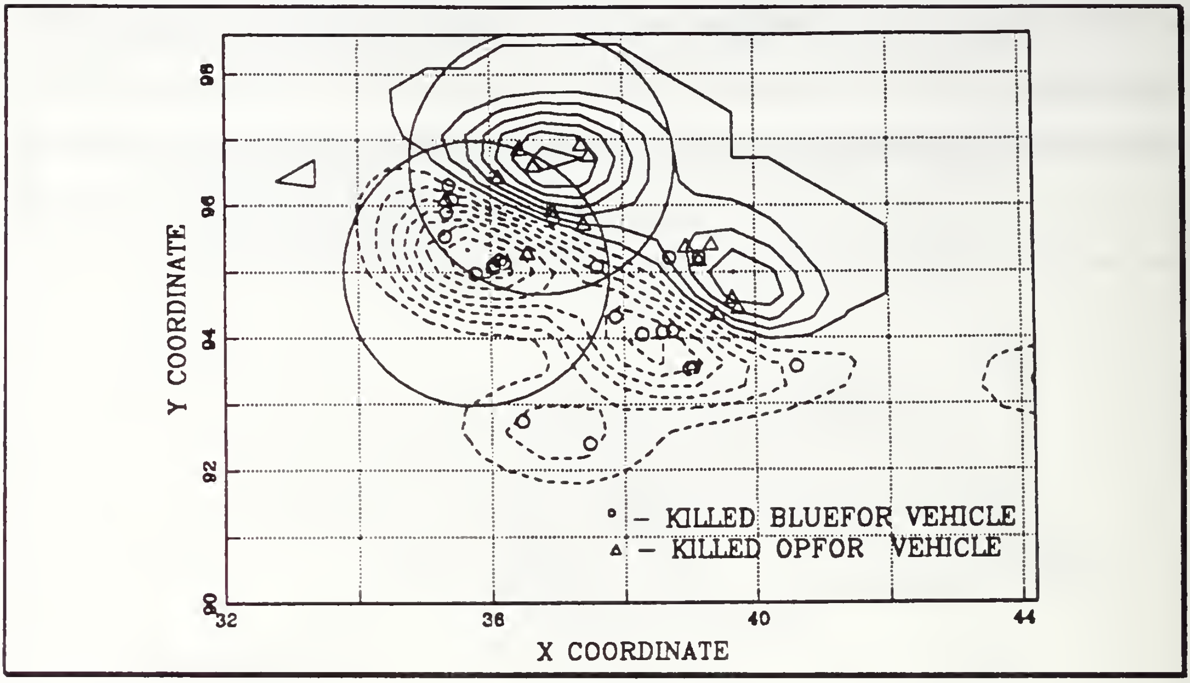

Figure 18. Deliberate Attack MA870212 Relative Attrition Surface Density Contour Magnification

3. Critical Ground Force Battle Time

The critical ground force attrition time for each mission was then derived, using the critical ground force attrition area obtained above. The kill times of OPFOR and BLUEFOR vehicles located in the critical attrition area were taken from the Screened Kill Event Table and compared to the times of all vehicles killed during the mission. This is shown in the histograms of Figure 19. The X axis represents 24 hour battle time in decimal numbers (7.5 is 07:30:00 hours). The time interval for each bar is 6 minutes. The Y axis represents the number of BLUEFOR and OPFOR kills in that 6 minute interval. The reason a histogram was used instead of techniques such as cosine smoothing functions was because of the preference to see an exact number of kills in each time interval. When comparing these two histograms for all selected missions, it appeared that the kill times were filtered from the entire battle area to the critical attrition area. The majority of kills in the critical attrition area always occurred in a shorter period of time than the majority of kills from the entire battle area. In the sample mission, this focused the critical attrition period down to approximately 08:15 to 09:00 hours.

A specific critical ground force attrition time had to be selected using the critical attrition area times shown in the lower histogram of Figure 19. This time would be used to take a "snapshot" of live vehicles on the battlefield and calculate concentration measures of these live vehicles. This shapshot needed to be taken just before the critical attrition period, since this is the logical time to have forces massed and the live vehicle concentration can be checked as a predictor of attrition. In order to avoid the early kills (outliers) and to have a standard rule for all missions, the critical ground force attrition time was defined as the time when 25 percent of kills had occurred in the critical ground force attrition area. In the sample battle, this time was 8.24 or 08:14:30 hours as shown in Figure 19.

B. DETERMINATION OF CONCENTRATION AT THE CRITICAL GROUND FORCE ATTRITION TIME

Two different concentration measures of live attacking vehicles at the critical ground force attrition time were obtained using the following techniques. First, the live vehicle position data was obtained from the Screened Ground Vehicle Position Location Table (SGPLT) as described in Chapter IV, Section D. These live vehicle locations formed a scatter plot of points, with grid coordinates represented by the X and Y axes as seen in Figure 20. The defending OPFOR vehicles are represented by triangles and the attacking BLUEFOR vehicles are represented by circles.

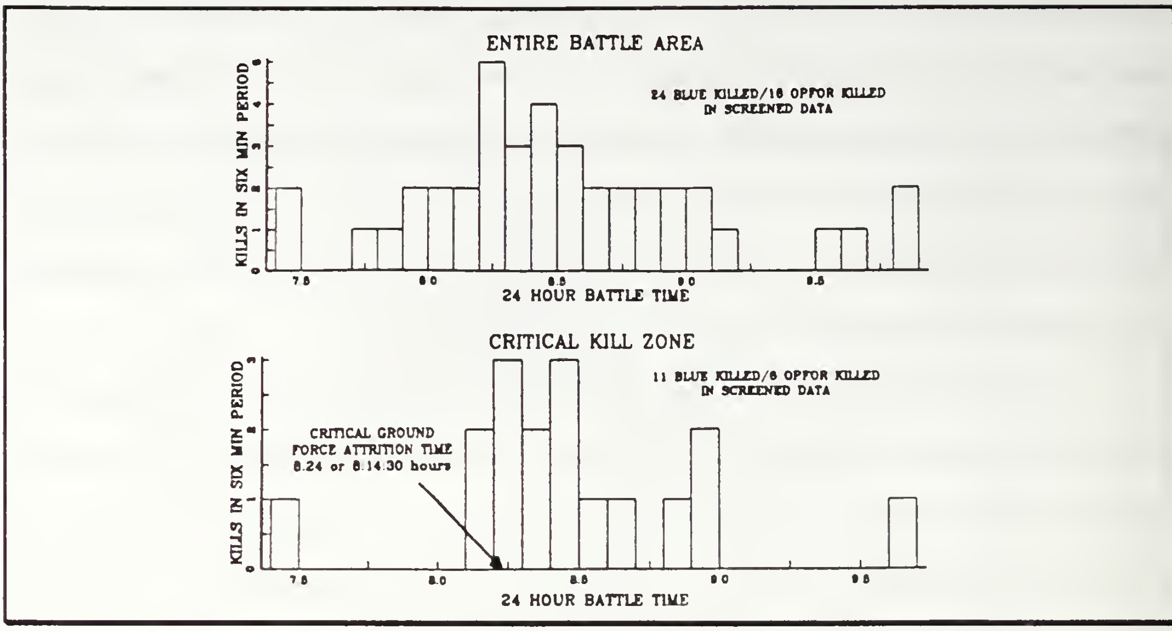

Figure 19. Deliberate Attack MA870212 Attrition Time Histograms

Although all OPFOR vehicles in the plot are instrumented, only a certain number are actually "playing" in this battle and defending terrain in the vicinity of the BLUEFOR objective. A density contour plot is taken of just these "playing" vehicles in order to get an idea of the center of the OPFOR defensive position. The OPFOR defensive position, with the same density contours is magnified in Figure 21. The approximate density center of the defensive position is shown with an X. The attacking BLUEFOR vehicle locations are now shown with their identification or "bumper" number which identifies the parent unit of the vehicle.

The first measure of ground force concentration dealt solely with the distance of live attacking vehicles from the center of the defensive position. The rectangular (X, Y) coordinate system was shifted to a (X', Y') system, so that the origin corresponded with the defensive position center. The distance from the origin (called r) was calculated for each attacking vehicle using the distance formula $r=\sqrt{X'^2+Y'^2}$. These distances were then used to find the circular radii (centered on the defensive position) enclosing 25, 50, and 75 percent of the attacking vehicles. This was accomplished by taking the first ($r_{Q(25)}$), second ($r_{Q(50)}$), and third ($r_{Q(75)}$) quartiles of the r distances. For example, the $r_{Q(25)}$ radius means that 25 percent of all vehicle locations fall within the radius and 75 percent of vehicles are outside the radius. Quartile radius $r_{Q(0)}$ is equal to zero, by definition. The above mentioned quartile radii formed the first category of ground force concentration predictor variables. The $r_{Q(25)}$ and $r_{Q(50)}$ circles are shown for mission MA870212 in Figure 21.

The second measure of ground force concentration is an area measure which combined the above quartile radii measures with a measure of the angular dispersion of attacking vehicles. The measure of attacking vehicle angular dispersion (called c) was obtained in the following manner. The location of attacking vehicles in (X', Y') rectangular coordinates was converted to (r, θ) polar coordinates. The conversion to r is shown above and θ is obtained from the relationship $\tan \theta = \frac{Y'}{X'}$. In APL, if the location is in the two left quadrants ($X' < 0$), θ has to be adjusted by Π, in order for its range to be -Π to Π.

The best fitted line from the origin through attacking vehicle locations was obtained using ordinary least squares regression applied in the polar framework, θ on r. This best fitting line corresponds to the actual aggregated task force attack axis. In the technique, vehicle locations were plotted in terms of r and θ, as shown on the left side of Figure 22. Locations that had a completely different direction and distance from the other locations were considered for exclusion as outliers. Such exclusions, however, happened very seldom; at most two locations were excluded in a mission. In the sample mission, no locations were excluded.

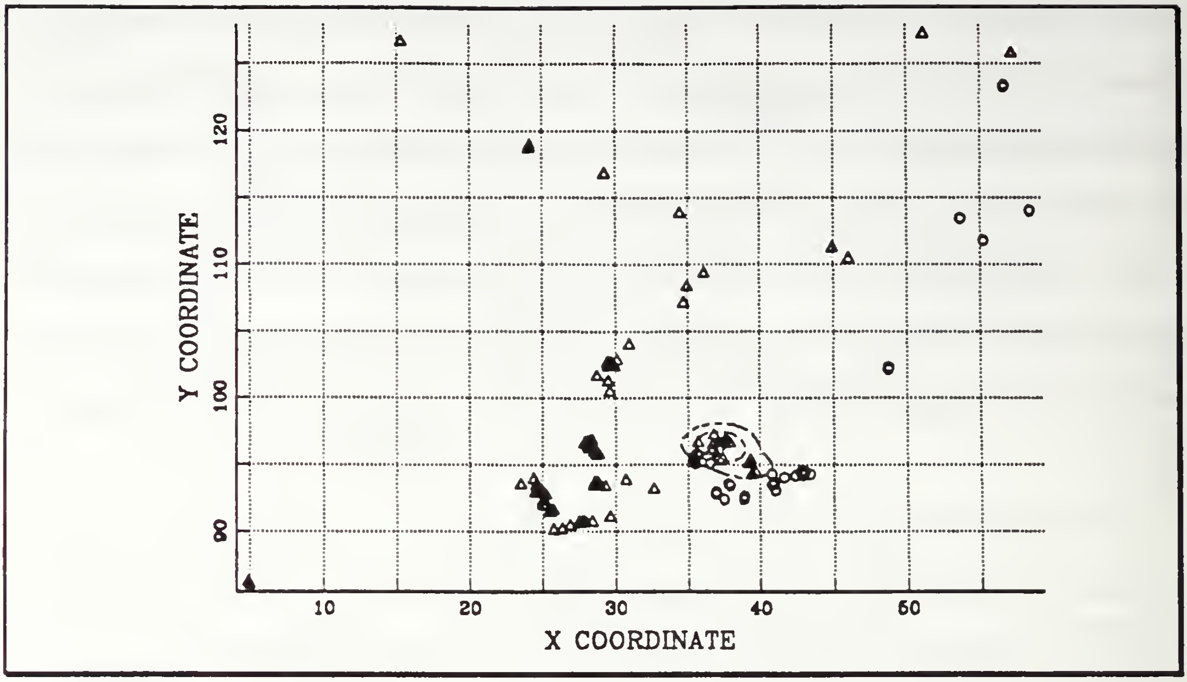

Figure 20. Deliberate Attack MA870212 Live Vehicle Locations at 08:14:00 hours

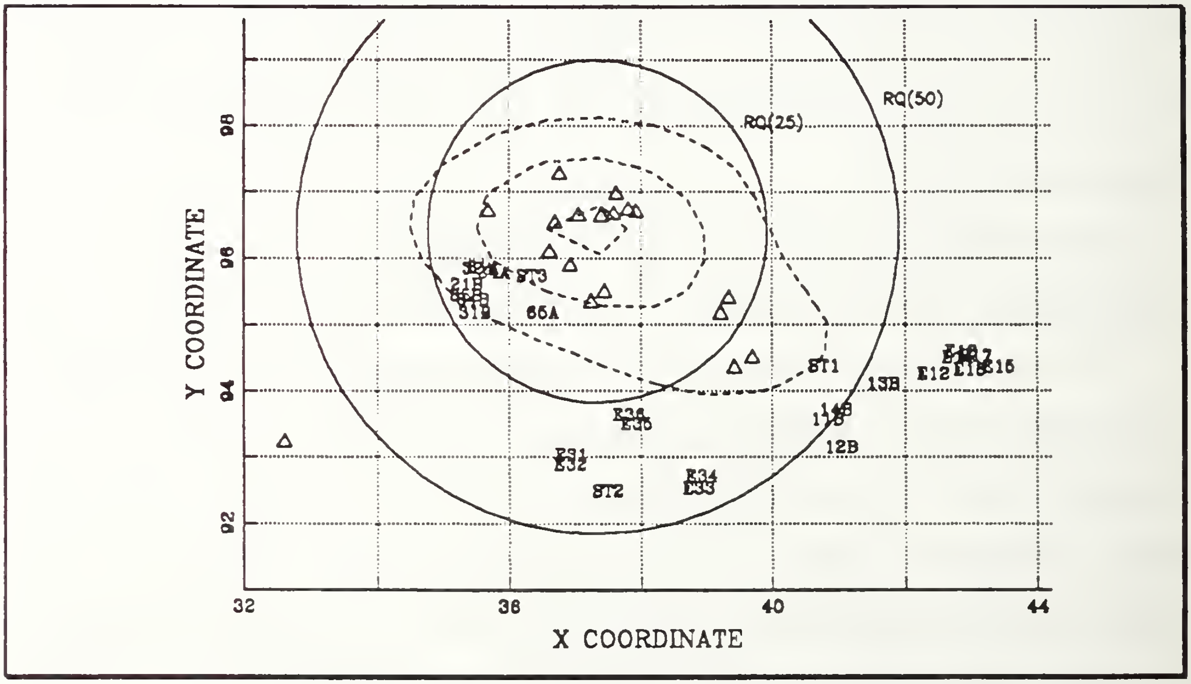

Figure 21. Deliberate Attack MA870212 Live Vehicle Location Magnification at 08:14:00 hours

Since the θ versus r plot showed a nonlinear trend, a power transformation (called rt) of the r coordinate was utilized with $rt = \frac{1}{p}(r^{p} - 1)$. The θ value plotted against rt is shown on the right side of Figure 22. The transformed plot appeared to be linear. Simple regression using the least squares method was then performed on the transformed data to find the best fitted line given by the equation $\hat{\theta} = a + b(rt)$. Using a power transformation value of $p = -\frac{1}{2}$ worked well in all selected missions to obtain a more linear trend and to improve the homogeneity of variance and the normality properties of the regression residuals.

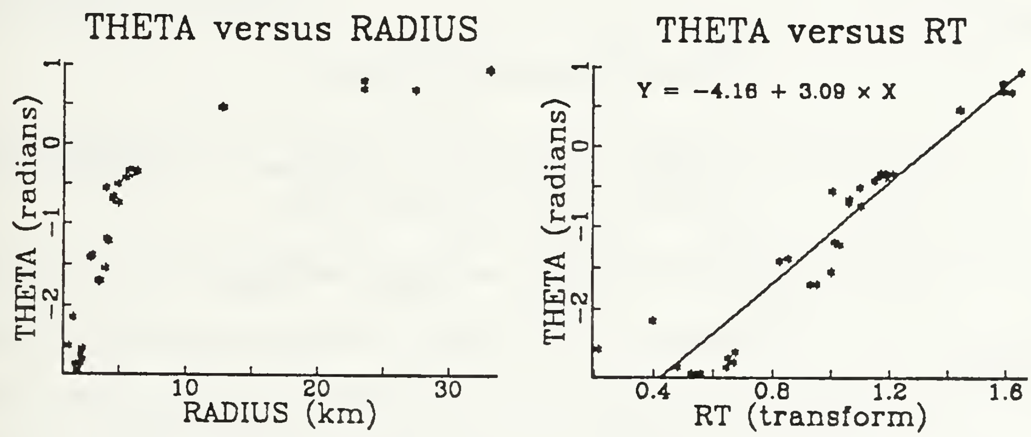

Figure 22. Deliberate Attack MA870212 θ versus r and rt Plots

The regression residuals (called rr) were then taken and the first ($rr_{Q(25)}$) and third ($rr_{Q(75)}$) quartiles calculated in order to find the interquartile range (IQR) of the rr distribution, using $rr_{IQR} = (rr_{Q(75)}) - (rr_{Q(25)})$. The relation of the interquartile range (IQR) to standard deviation (σ) is $1.5(IQR) \approx 2\sigma$. Using $c = 1.5(IQR)$ as the measure of angular dispersion, the fitted regression equation was modified to:

$$\theta = a + b(rt) \pm c, \text{ where } \quad \begin{aligned} \theta_{UPPER} &= a + b(rt) + c \\ \hat{\theta} &= a + b(rt) \\ \theta_{LOWER} &= a + b(rt) - c \end{aligned}$$

The fitted lines corresponding to (r, θ_{UPPER}) and (r, θ_{LOWER}) are shown for the sample mission in Figure 23, as well as the circles corresponding to the $r_{Q(25)}$ and $r_{Q(50)}$ quartile radii.

The second measure of ground force concentration was then derived as the area in Figure 23, bounded by the θ_{UPPER}, θ_{LOWER} fitted lines and selected quartile radii. This area, which is shaped as a cornucopia, was obtained by the following integration:

$$\text{Area} = \iint_A dx\, dy = \iint_{A'} r\, dr\, d\theta$$

where $A' = A'(r, \theta)$ is the image of A in polar coordinates. When the power transform was made

$$rt = \frac{1}{p}\left(r^{p} - 1\right) \qquad drt = r^{p-1} dR$$

or inversely

$$r = [1+p(rt)]^{\frac{1}{p}} \qquad dr = [1+p(rt)]^{\frac{1}{p} - 1} .$$

Then

$$\text{Area} = \iint_{A''} [1+p(rt)]^{\frac{1}{p}} [1+p(rt)]^{\frac{1}{p} - 1} \; drt\, d\theta .$$

This had the advantage that A" is a parallelogram in the (rt, θ) plane

$$\theta = a + b(rt) \pm c$$

where c was chosen to get a desired probability level of angular dispersion. So,

$$\text{Area} = \int_{rt_{Q(0)}}^{rt_{Q(25)}} \left(\int_{a+b(rt)+c}^{a+b(rt)-c} d\theta \right) [1+p(rt)]^{\frac{1}{p}} [1+p(rt)]^{\frac{1}{p}-1} \, drt$$

$$= 2c \int_{rt_{Q(0)}}^{rt_{Q(25)}} [1+p(rt)]^{\frac{2}{p}-1} \, drt$$

where $rt_{Q(0)}$ and $rt_{Q(25)}$ are transforms of the selected quartile radii.

To integrate, let

$$w = [1+p(rt)]^{\frac{2}{p}} \qquad dw = 2[1+p(rt)]^{\frac{2}{p}-1} \, drt.$$

Then

$$\text{Area} = 2c \int_{w_{Q(0)}}^{w_{Q(25)}} \frac{dw}{2} = 2c[w_{Q(25)} - w_{Q(0)}].$$

Tracing back to r showed

$$w = [1+p(rt)]^{\frac{2}{p}} = [r^{p}]^{\frac{2}{p}} = r^{2}.$$

In conclusion,

$$\text{Area} = c[r_{Q(25)}{}^{2} - r_{Q(0)}{}^{2}] = c[r_{Q(25)}{}^{2}]$$

if the zero and first quartile radii were selected for integration limits. This area formed the second category of ground force concentration predictor variables, which combined the quartile radii (r_Q) with a measure of the attacking force's angular dispersion (c). Both categories of predictor variables are checked in Chapter VIII for correlation to the deliberate attack measure of effectiveness for each mission.

Figure 23 is the graphical predictor variable representation for the sample "good" BLUEFOR deliberate attack with MOE of 67.16 percent. To contrast, Figure 24 shows a "bad" BLUEFOR deliberate attack (MA880324) that has an MOE of 25.52 percent. This mission occurred near TV Hill in the Hill 909 training area with the task force attacking west. Finally, Figure 25 shows one of the OPFOR attacks (AA870225), with an MOE of 53.19 percent. This OPFOR attack occured in the Siberia training area. The concentration predictor variables shown in Figures 23, 24, and 25 are further analyzed and discussed in Chapters VIII and IX.

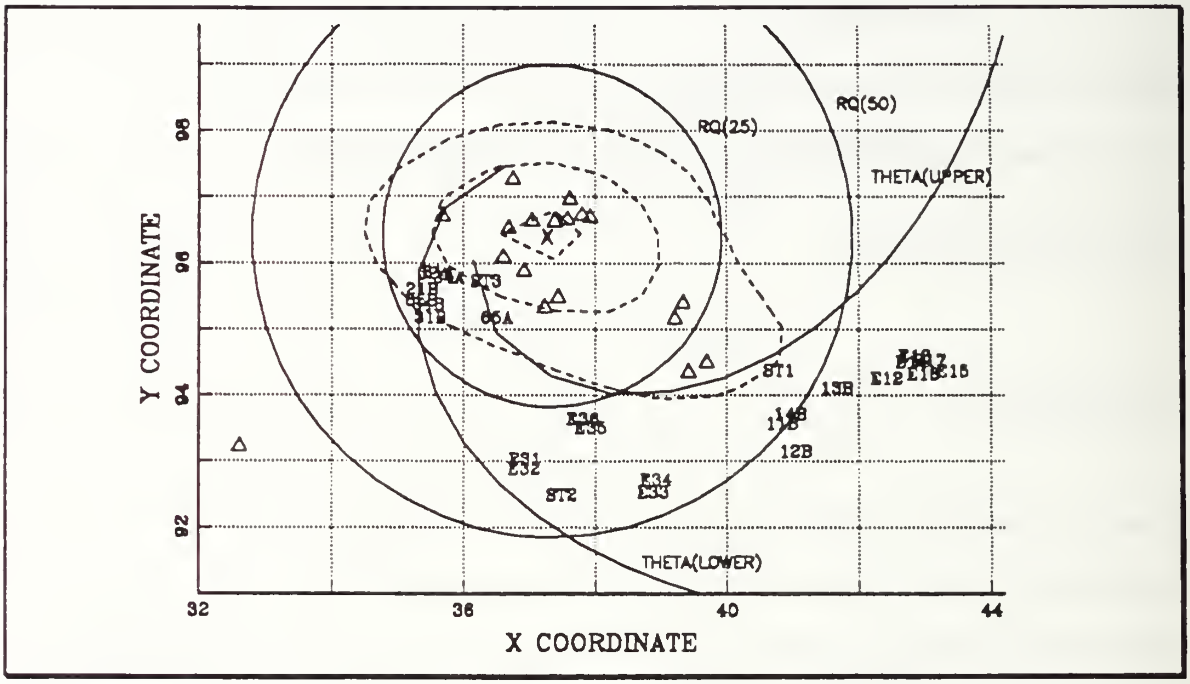

Figure 23. BLUEFOR Deliberate Attack MA870212 Concentration Graphics

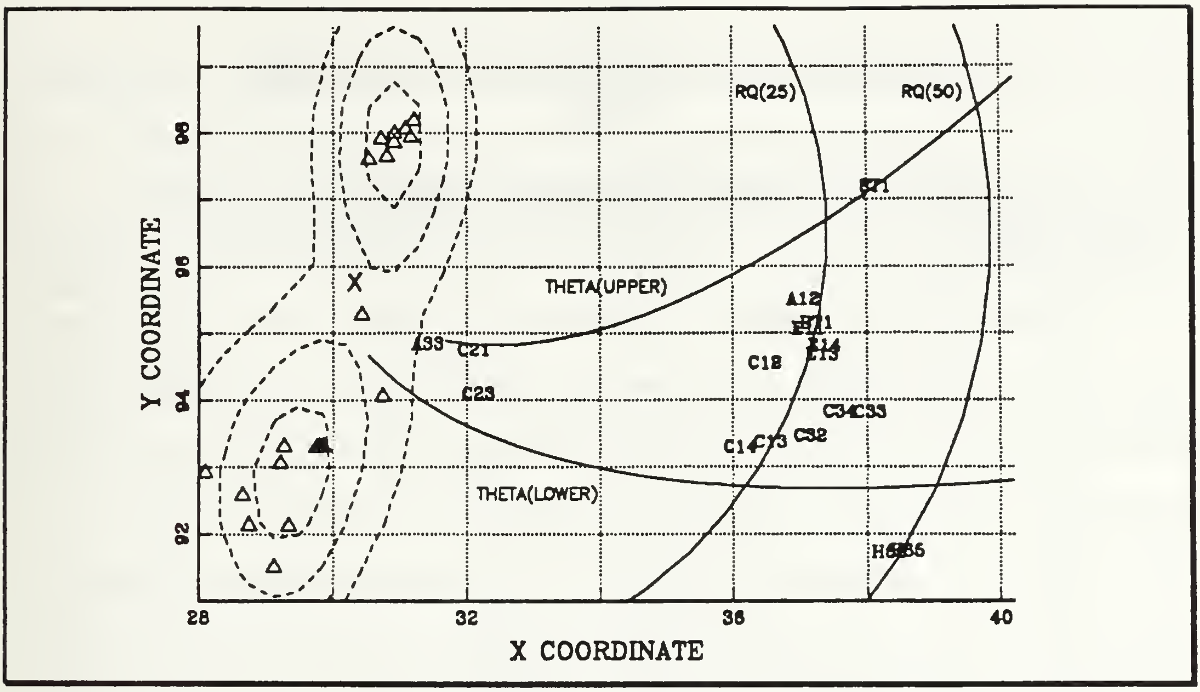

Figure 24. BLUEFOR Deliberate Attack AA880324 Concentration Graphics

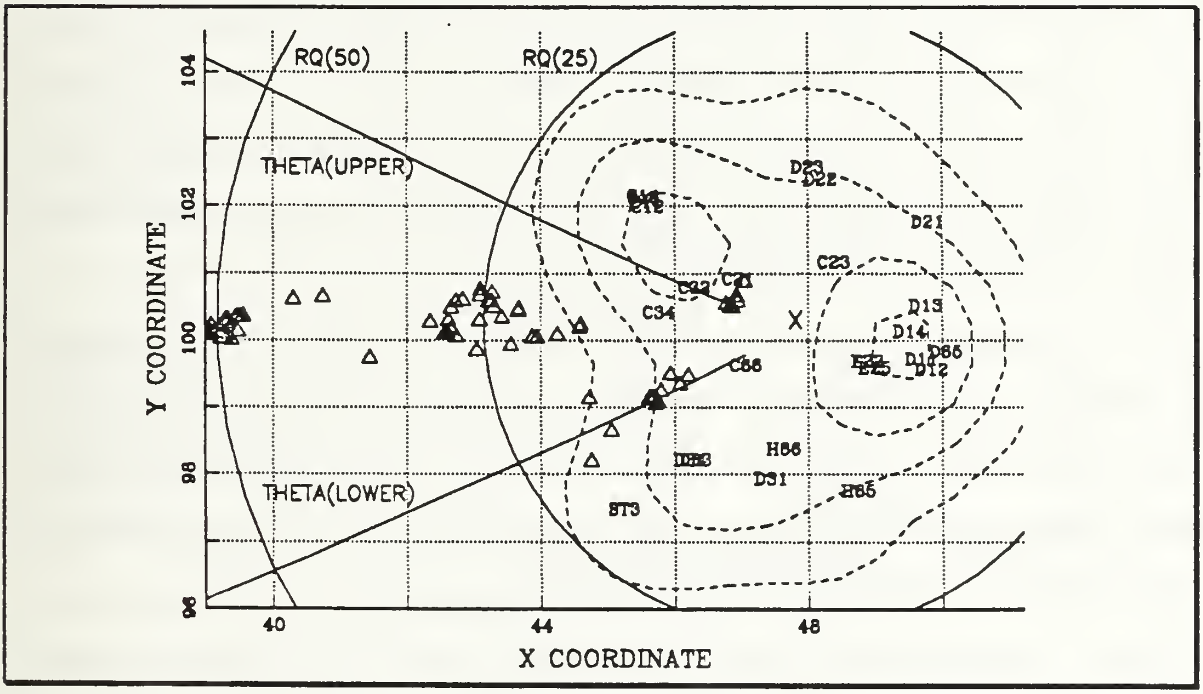

Figure 25. OPFOR Attack AA870225 Concentration Graphics

VIII. RESULTS AND DATA ANALYSIS

A. COMPARISON OF SCREENED KILL EVENT DATA WITH SUMMARY KILL DATA FROM MISSION TAKE HOME PACKETS

The deliberate attack measure of effectiveness (response variable) described in Chapter VI, Section B is based on the summary attrition data in each mission's Take Home Packet. This is the most accurate summary kill data available, since it was produced by NTC observer controllers, but the time associated with each kill is not listed. In order to derive the ground force concentration (predictor variables) in Chapter VII, kill event times were needed. Therefore, the screened kill event table (SKET) was taken from the NTC database. The SKET kill data is not as accurate as data from the take home packet, due to the NTC instrumentation problems discussed in Chapter IV, Section A. A comparison of tank killing armored vehicle kills in the SKET versus the Take Home Packet is listed in Table 12. Also, the initial BLUEFOR and OPFOR force levels are shown. The average percentage of Take Home Packet kills that are listed in the SKET is 77.5% for selected BLUEFOR attacks, 51.7% for selected OPFOR attacks, and 72.4% overall. These discrepancies in the attrition data will induce a larger unexplained variance when comparing predictor and response variables. The highlighted BLUEFOR mission MA870317 and OPFOR mission AA880320 had the lowest percent correlation between Take Home Packet and SKET kill data. These two missions are discussed further in Section C below. Since the SKET is the most accurate source of kill event data available from each mission, it was assumed that the SKET data is a representative sample of the total kills recorded in the take home packet.

TABLE 12. ATTRITION DATA FROM TAKE HOME PACKET AND SKET

Mission (Chronological)	BLUEFOR Initial Force	OPFOR Initial Force	BLUEFOR Killed SKET/THP	OPFOR Killed SKET/THP	% Kill Comparison (SKET÷THP)*100
BLUEFOR DELIBERATE ATTACKS					
MA870212	41	14	24/24	16/13	108.1
MA870220	38	14	20/23	13/13	91.7
AA870220	34	14	6/14	3/10	37.5
AB870301	32	27	20/27	5/10	67.6
MA870317	***37***	***15***	***4/18***	***4/6***	***33.3***
MA870319	33	14	24/22	11/12	102.9
AA870432	32	14	11/21	7/6	66.6
MA870604	42	17	18/21	13/9	103.3
MA870626	39	16	23/26	17/16	95.2
MA870806	40	162	30/30	38/58	63.6
MA870828	45	22	24/34	6/9	69.8
AA871115	32	16	11/27	19/7	88.2
MA871233	33	18	17/24	12/16	72.5
MA871308	40	22	26/29	8/2	109.7
MA871409	44	13	26/32	8/12	77.3
AA871421	36	16	28/28	10/15	88.4
MA880212	39	28	18/27	9/5	84.4
MA880220	27	34	6/12	5/11	47.8
AA880324	32	30	16/21	3/5	73.1
MA880422	31	14	14/18	6/4	90.9
AA880614	37	22	16/20	3/4	79.2
AA880627	39	9	16/26	15/7	93.9
MA880632	42	42	22/18	12/35	64.2
MA881053	38	38	24/32	13/38	52.9
				Mean BLUEFOR % Kill Comparison:	77.5
OPFOR ATTACKS					
AA870225	37	134	15/25	50/82	60.7
MA871312	36	131	24/24	43/53	87.0
AA880212	36	139	14/34	29/81	37.4
AA880320	***36***	***126***	***1/28***	***2/41***	***4.3***
MA880415	37	141	18/33	29/40	64.4
MA880618	38	127	23/27	55/105	56.5
				Mean OPFOR % Kill Comparison:	51.7
				Mean Total % Kill Comparison:	72.4

B. REGRESSION DATA ANALYSIS METHODOLOGY

Simple regression using the least squares method was conducted to check how much of the variation in the deliberate attack MOE (response variable) could be explained by each of the predictor variables. The simple regression model, in which there is only one predictor variable is

$$y = \beta_o + \beta_1 x + \varepsilon$$

where $\beta_o + \beta_1 x$ is the relationship between x and y and ε is the error term, which could be caused by model error, if all relevant predictors were not considered, or random error. The regression equation derived from this model is

$$\hat{y} = b_o + b_1 x$$

where b_o is the regression constant, b_1 is the regression coefficient, and $\hat{y}$ is the predicted (fitted) value of y, given x. The significance level ($\hat{\alpha}$) of the regression analysis of variance (ANOVA) table was initially checked to see if $\hat{\alpha} < .05$. This is the conventional α level for rejecting the null hypothesis that $\beta_1 = 0$. Also, the square of the correlation coefficient (R^2) was calculated. R^2 is the fraction of the variation in the response variable (y) that is explained by the predictor variable (x).

If the $\hat{\alpha}$ and R^2 measures were promising, the homogeneity of variance and normality assumptions in the least squares regression method were checked. The homogeneity of variance was tested by splitting the residual data in half (Res_1, Res_2), ordered on the predictor variable x. The sample variance was calculated for each half using

$$S^2_{Y|X(1)or(2)} = \frac{\Sigma(Res - \mu_{Res1or2})^2}{(n_{1or2} - 1)}.$$

Then, the F statistic was obtained by dividing the larger sample variance into the smaller sample variance

$$F = \frac{S^2_{Y|X(1)}}{S^2_{Y|X(2)}} \qquad \text{or} \qquad F = \frac{S^2_{Y|X(2)}}{S^2_{Y|X(1)}}$$

with degrees of freedom

$$\upsilon_1 = n_1 - 2, \upsilon_2 = n_2 - 2 \qquad \text{or} \qquad \upsilon_1 = n_2 - 2, \upsilon_2 = n_1 - 2.$$

The significance level ($\hat{\alpha}$) of the null hypothesis $\sigma_1 = \sigma_2$ could then be compared to see if $\hat{\alpha} > .05$, which would indicate homogeneity of variance. Normality of residuals was tested using the χ^2 goodness of fit test. This involved grouping standardized residuals into categories and comparing the actual frequencies (F) with the theoretical frequencies (f). The null hypothesis is that the residuals are normal with mean = 0 and variance = $S^2_{Y|X}$. If this null hypothesis is true,

$$\chi^2 < \sum \frac{(F - f)^2}{f}, \text{ with degree of freedom } \upsilon_1 = \text{\# of categories } - 2.$$

Multiple regression could be used to check more than one predictor variable according to the model

$$y = \beta_o + \beta_1 x_1 + \ldots + \beta_k x_k + \varepsilon$$

and fitted equation

$$\hat{y} = b_o + b_1 x_1 + \ldots + b_k x_k.$$

However, multicollinearity, or correlation between predictor variables (x_k), has to be checked, since if serious multicollinearity exists among predictor variables, the regression coefficients (b_k) are not good predictors and their effects are confounded with other coefficients.

C. RESULTS AND ANALYSIS OF QUARTILE RADII CONCENTRATION VS DELIBERATE ATTACK MOE

The $r_{Q(25)}$, $r_{Q(50)}$, $r_{Q(75)}$ quartile radii concentration measures are listed in Table 13 for all selected BLUEFOR and OPFOR attack missions. It became immediately apparent that highlighted BLUEFOR mission MA870317 and OPFOR mission AA880320 were outliers in all quartile radii categories. Upon checking the attrition data comparison in Table 12, the reason became clear. These two missions had the lowest percent correlation between Take Home Packet and SKET kill data. The two missions were eliminated from the rest of the analysis based on SKET kill data not adequately representing actual kill events.

The regression fit of the BLUEFOR deliberate attack MOE against quartile radii is shown in Figure 26. The $r_{Q(25)}$ and $r_{Q(50)}$ regression significance levels ($\hat{\alpha}$) are both less than .05. The square of the correlation coefficient (R^2) shows a moderate (.405 for $r_{Q(25)}$) and a moderately low (.252 for $r_{Q(50)}$) fraction of the MOE variance explained by the predictor variable. The homogeneity of variance and normality assumptions appeared valid for the $r_{Q(25)}$ and $r_{Q(50)}$ fits, as shown in Table 14. Therefore, $r_{Q(25)}$ and $r_{Q(50)}$ appear to have a statistically significant effect on the deliberate attack MOE. Multiple regression was not conducted in this category because of the obvious multicollinearity (or correlation) between quartile radii measures for each mission.

The regression fit of the OPFOR attack MOE against quartile radii is shown in Figure 27. The regression significance levels ($\hat{\alpha}$) are all greater than .05 and the squares of the correlation coefficient (R^2) are low. This lack of regression fit could be caused by a small sample size and a small range of the attack MOE (48 - 72 percent).

TABLE 13. QUARTILE RADII RESULTS

Mission (MOE Ranked)	MOE (%)	Quartile Radius $r_{Q(25)}$ (km)	Quartile Radius $r_{Q(50)}$ (km)	Quartile Radius $r_{Q(75)}$ (km)
BLUEFOR DELIBERATE ATTACKS				
MA880632	70.238	3.017	4.405	12.220
MA870212	67.160	2.581	4.554	12.818
MA870626	66.667	1.769	2.400	5.072
MA870220	66.165	2.004	5.351	31.549
AA870220	65.126	1.831	3.065	12.338
MA871409	59.790	2.729	3.017	3.799
MA870319	59.524	4.239	4.787	12.218
MA871233	58.081	4.126	4.857	15.967
AA871421	57.986	1.352	4.427	7.853
MA881053	57.895	2.929	3.380	7.524
AA880627	55.556	4.049	6.907	21.794
MA870604	51.471	3.458	4.812	6.213
MA870317	***45.676***	***10.319***	***14.814***	***17.991***
MA880220	43.954	3.979	4.634	7.384
AA870432	38.616	3.136	3.961	13.396
MA880422	35.253	4.306	6.050	13.894
MA870828	32.677	2.600	2.943	3.469
AA880614	32.064	5.787	7.794	11.967
MA870806	30.401	4.148	4.869	7.751
AA871115	29.688	4.488	12.120	18.476
AB870301	26.331	3.331	4.628	8.035
AA880324	25.521	6.635	9.104	16.807
MA880212	24.313	3.148	4.506	7.975
MA871308	18.295	5.456	7.471	9.253
OPFOR ATTACKS				
MA880415	80.410	6.386	8.532	12.978
AA880320	***72.619***	***15.101***	***16.586***	***17.485***
AA880212	68.086	1.545	3.031	12.678
MA871312	63.104	4.209	7.823	14.308
AA870225	53.187	4.653	8.620	16.658
MA880618	48.554	3.722	8.156	16.334

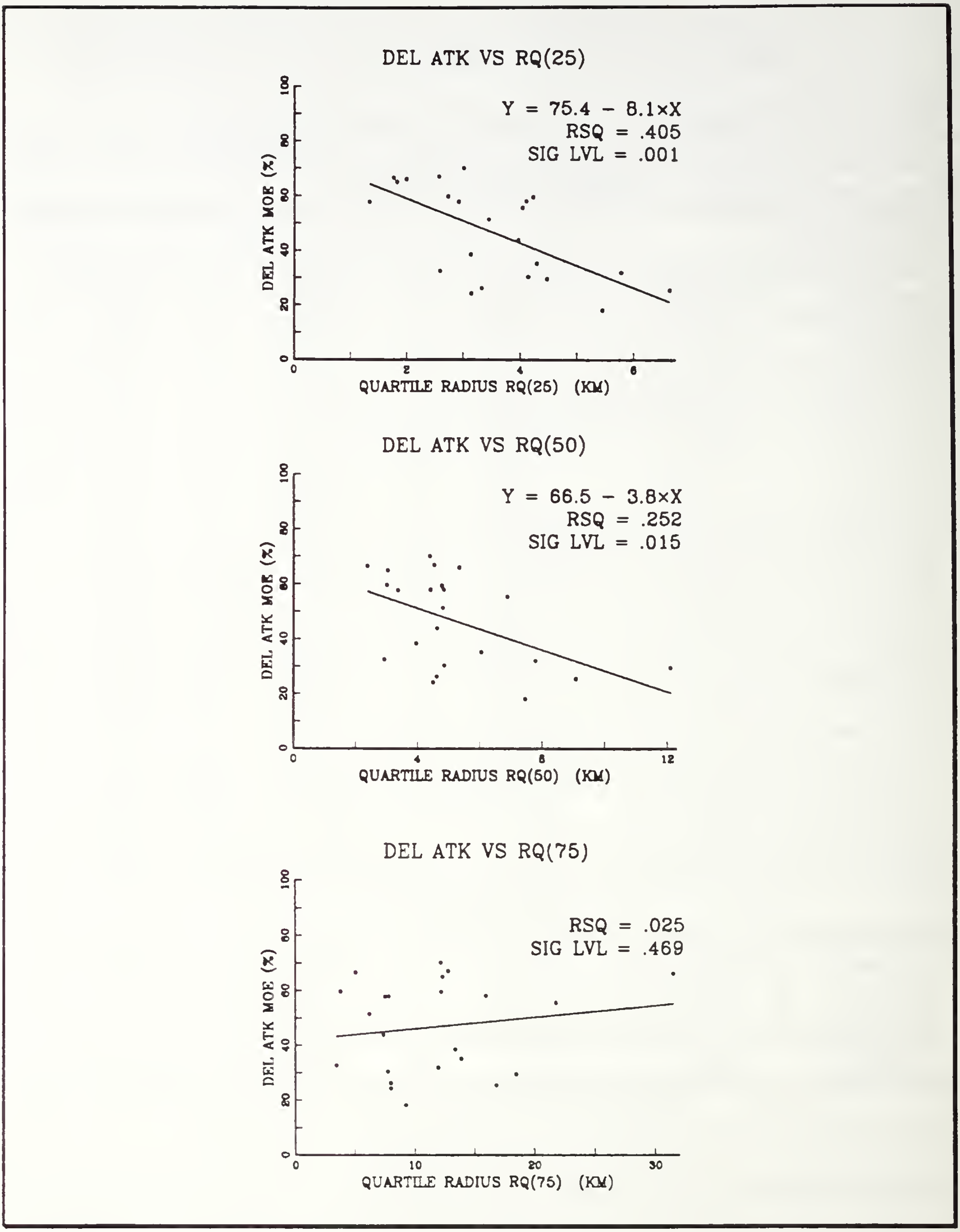

Figure 26. BLUEFOR Deliberate Attack MOE against Quartile Radii

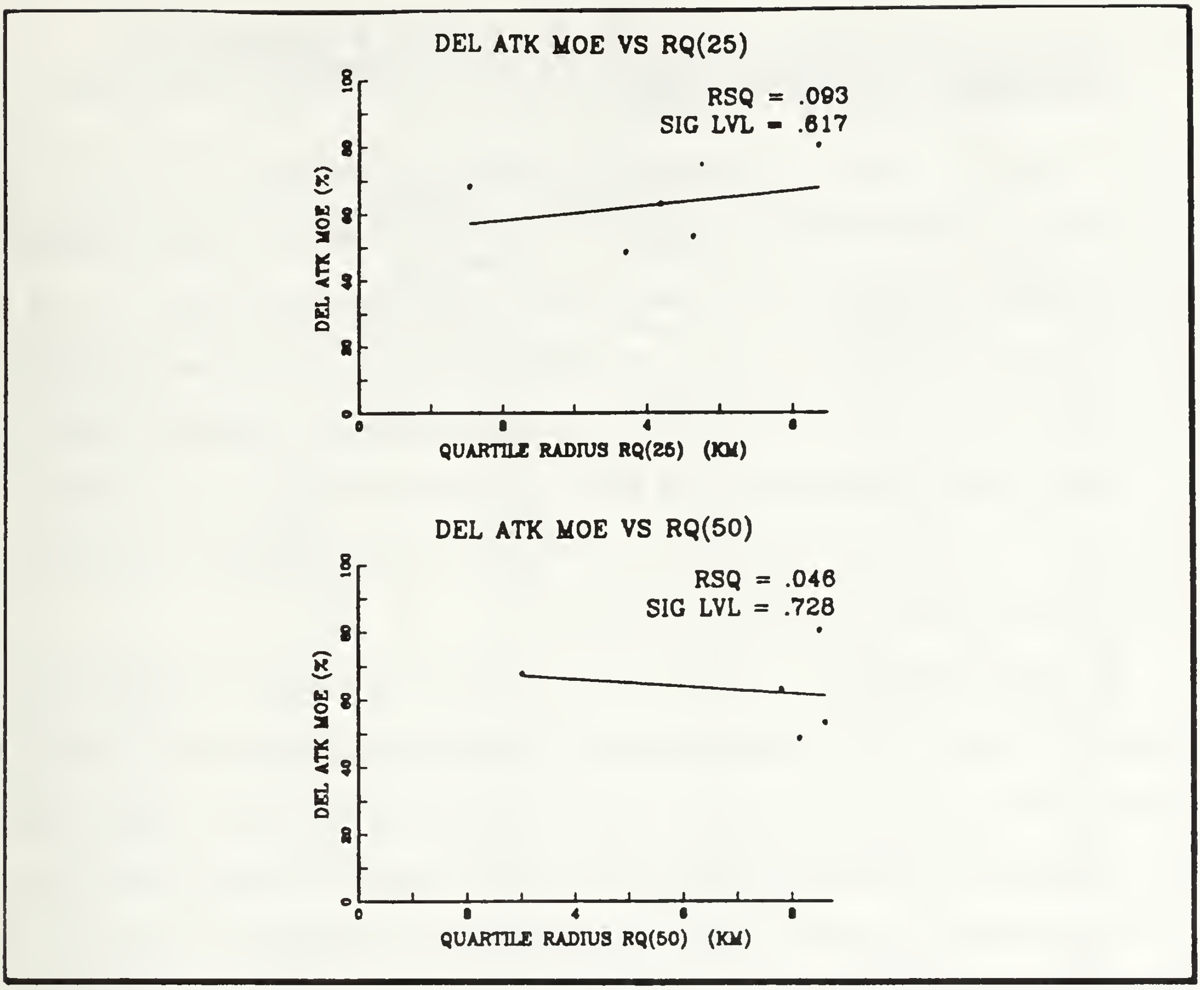

Figure 27. OPFOR Deliberate Attack MOE against Quartile Radii

TABLE 14. HOMOGENEITY OF VARIANCE AND NORMALITY TEST RESULTS FOR $r_{Q(25)}$ AND $r_{Q(50)}$

Homogeneity of Variance	Normality				
F	Categories	F for $r_{Q(25)}$	F for $r_{Q(50)}$	f	χ^2
1.86 for $r_{Q(25)}$	$-\infty < \ \leq -.5$	7	7	6.693	2.67 for $r_{Q(25)}$
1.47 for $r_{Q(50)}$	$-.5 < \ \leq 0$	2	3	4.807	3.01 for $r_{Q(50)}$
3.14 for $F_{.95}$ 10,9 d.f.	$0 < \ \leq .5$	7	3	4.807	5.99 for $\chi^2_{.95}$ 2 d.f.
	$.5 < \ \leq \infty$	7	7	6.693	

D. RESULTS AND ANALYSIS OF QUARTILE RADIUS AND ANGULAR DISPERSION AREA OF CONCENTRATION VS DELIBERATE ATTACK MOE

The angular dispersion (c) and area of concentration measure ($c[r_{Q(25)}]^2$) are listed in Table 15 for all selected BLUEFOR and OPFOR attack missions. When both these measures were plotted against the deliberate attack MOE, the density of points was not uniform; point density was shifted to the left. To even the density of points, the power transform ($\sqrt{c}$) and area transform ($\sqrt{c}[r_{Q(25)}]$) were taken and the regression fit of the deliberate attack MOE against these transforms is shown in Figure 28. The regression significance levels ($\hat{\alpha}$) are all greater than .05 and the squares of the correlation coefficient (R^2) are low.

The angular dispersion measure c does not appear to have a statistically significant influence on the deliberate attack MOE when compared alone, or when combined with $r_{Q(25)}$ in the area concentration measure for all missions. Again, with OPFOR missions, this lack of regression fit could be caused by a small sample size and a small range of the attack MOE. The OPFOR plots in Figures 27 and 28 can, however, show a rough OPFOR estimate of the selected concentration measures.

A multiple regression was conducted on the deliberate attack MOE against both $r_{Q(25)}$ and $\sqrt{c}$. The best fitting equation was $\hat{y} = 68.51 - 7.76r_{Q(25)} + 6.99\sqrt{c}$ and the R^2 was .413, a slight improvement in the simple regression R^2 of .405 for $r_{Q(25)}$. The correlation between the two predictor variables was low with a correlation coefficient of .29.

TABLE 15. QUARTILE RADIUS AND ANGULAR DISPERSION AREA RESULTS

Mission (MOE Ranked)	MOE (%)	Angular Dispersion C (radians)	Angular Transform $\sqrt{C}$	Area Measure $C[r_{Q(25)}{}^2]$ (km^2)	Area Transform $\sqrt{C}[r_{Q(25)}]$
BLUEFOR DELIBERATE ATTACKS					
MA880632	70.238	0.762	.873	6.940	2.634
MA870212	67.160	0.647	.804	4.308	2.076
MA870626	66.667	1.036	1.018	3.242	1.801
MA870220	66.165	0.680	.824	2.731	1.652
AA870220	65.126	0.505	.711	1.695	1.302
MA871409	59.790	1.883	1.372	14.025	3.745`
MA870319	59.524	1.325	1.151	23.800	4.879
MA871233	58.081	0.390	.625	6.641	2.577
AA871421	57.986	0.602	.776	1.101	1.049
MA881053	57.895	0.914	.956	7.842	2.800
AA880627	55.556	0.283	.532	4.646	2.155
MA870604	51.471	0.358	.598	4.277	2.068
MA880220	43.954	0.218	.467	3.459	1.860
AA870432	38.616	0.621	.788	6.112	2.472
MA880422	35.253	0.615	.784	11.397	3.376
MA870828	32.677	0.983	.991	6.642	2.577
AA880614	32.064	0.243	.493	8.126	2.851
MA870806	30.401	0.474	.689	8.160	2.857
AA871115	29.688	0.508	.713	10.240	3.200
AB870301	26.331	0.304	.551	3.369	1.835
AA880324	25.521	0.318	.564	14.005	3.742
MA880212	24.313	0.495	.703	4.906	2.215
MA871308	18.295	1.112	1.055	33.106	5.754
OPFOR ATTACKS					
MA880415	80.410	0.433	.658	17.656	2.765
AA880212	68.086	0.922	.960	2.201	1.425
MA871312	63.104	0.435	.660	7.711	1.832
AA870225	53.187	0.372	.610	8.061	1.733
MA880618	48.554	0.705	.840	9.772	2.626

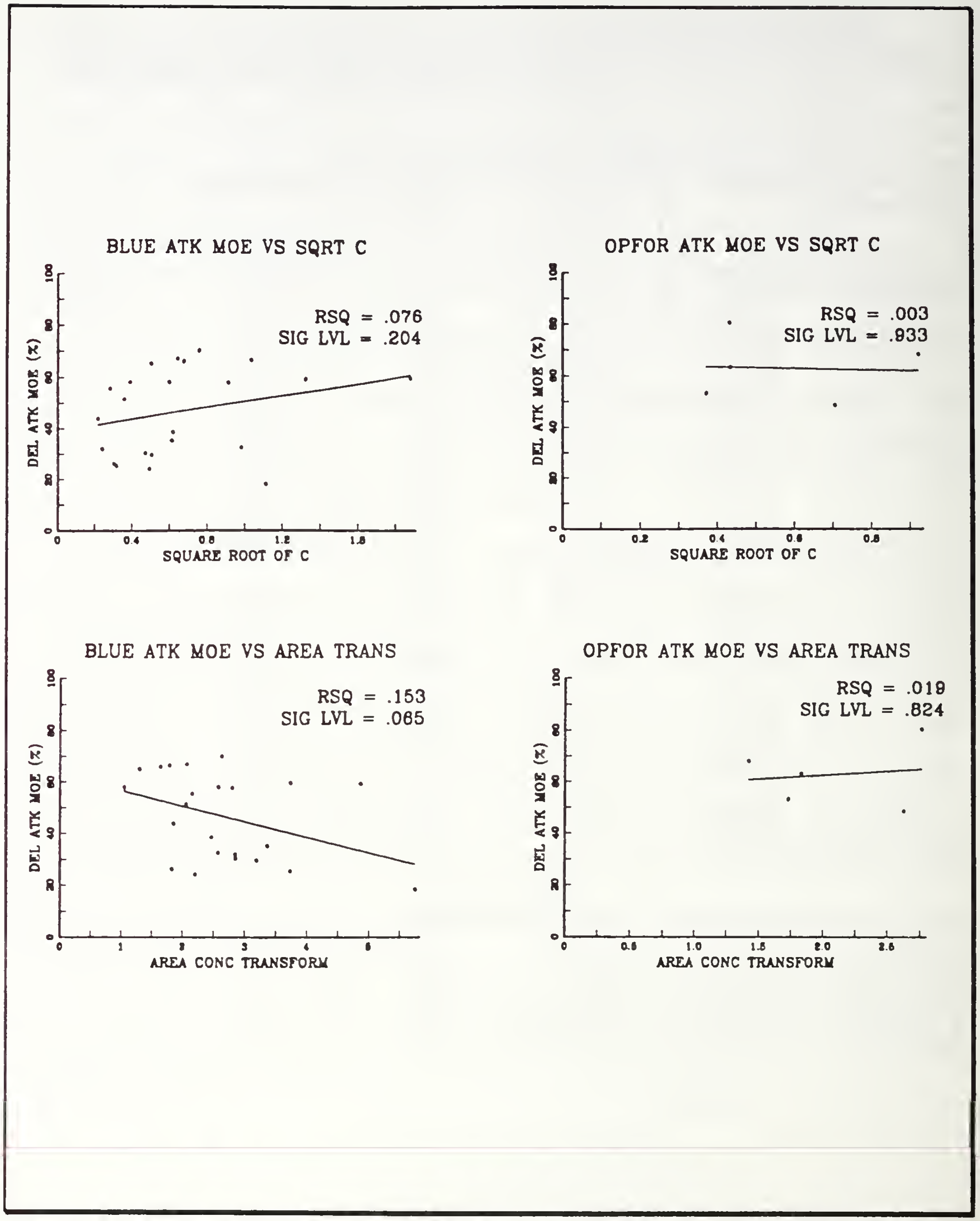

Figure 28. Deliberate Attack MOE against Angular Dispersion and Area Transforms

IX. CONCLUSIONS AND MILITARY APPLICABILITY

A. CONCLUSIONS

The following hypothesis was tested for validity. Given a task force deliberate attack mission conducted under NTC conditions, there exists a relationship between the degree of ground force concentration at the battle point of critical attrition (predictor variable) and a deliberate attack MOE (response variable). Two categories of predictor variables were developed. The first category used quartile radii measures as a way to measure the closeness of the attacking force to the center of the defending force at the critical ground force attrition time. The radius quartile that measured the distance of the closest 25 percent of attackers ($r_{Q(25)}$) had the best statistically significant relationship (for a single predictor) to the deliberate attack MOE, with an R^2 value of .405. The radius quartile $r_{Q(50)}$ also had a statistically significant relationship with an R^2 value of .252, as shown in Chapter VIII, Section B.

There are obviously other predictor variables that influence this attrition-based deliberate attack MOE. However, when studying the scatter plot of these two quartile radii, it appears that the massing of combat power at the critical attrition time is a *prerequisite* to mission success. Task forces with deliberate attack MOEs above 50 percent have all massed 25 percent of their combat power within approximately 4 kilometers of the enemy center. These same successful units have all massed 50 percent of their combat power within approximately 5 kilometers of the enemy center. This massing of combat power does not ensure mission success. There are units that have achieved the appropriate 25 and 50 percent quartile radii, but still have a MOE much below 50 percent. Once a task force's combat power is appropriately massed, the unit has to convert this combat potential into enemy attrition and friendly survival through synchronized direct fire and maneuver, in combination with other combat multipliers.

The effect of attacking force closeness is clearly seen in the five OPFOR attacks analyzed. Even though these were regimental attacks with approximately 140 vehicles (versus BLUEFOR task force attacks of approximately 40 vehicles), the 25 percent concentration radius was consistently under 6 kilometers. The MOE performance of these OPFOR attacks was good since they were centered above 50 percent.

The second category of predictor variables dealt with angular dispersion (c) and a derived area of concentration ($c[r_{Q(25)}]^2$). Their effect on BLUEFOR deliberate attack performance is not clear from this analysis. The transformed angular dispersion ($\sqrt{c}$) and area measures ($\sqrt{c}[r_{Q(25)}]$) did not significantly correlate with the MOE, using simple regression analysis, as shown in Chapter VIII, Section D. A multiple regression was conducted on the deliberate attack MOE against both $r_{Q(25)}$ and $\sqrt{c}$, but the resulting R^2 of .413 was only a slight improvement in the simple regression R^2 of .405 for $r_{Q(25)}$.

As discussed in Chapter V, task forces should doctrinally isolate and exploit a weakly defended penetration site during the deliberate attack, in order to defeat the enemy in detail with overwhelming combat power. Therefore, successful attack missions should doctrinally show relatively narrow angular dispersion and a smaller area of concentration at the critical ground force attrition time. The fact that this trend was not seen might be due to some successful units not using these doctrinal tactics, or due to accuracy and variance problems in the selected data.

When the five OPFOR attacks were checked for angular dispersion and area of concentration, the results seemed more consistent than with the BLUEFOR attacks. Even with approximately three times the number of combat vehicles, the angular dispersion was consistently below .9 radians, which indicates a narrow attack dispersion at the critical ground force attrition time.

B. MILITARY APPLICABILITY

The following list summarizes the possible applications of the methodology and results of this thesis:

- The $r_{Q(25)}$ and $r_{Q(50)}$ predictor variables can be used as training standards to check a task force's ability to mass forces at the battle critical attrition point. Also, commanders can use these standards as a deliberate attack mission goal in training for NTC.
- The screening procedure used to obtain kill event data and live vehicle positions is currently the most accurate way to filter this information in the ARI-POM CTC Archive. This procedure is automated and can be modified to suit other event queries.
- The methodology of deriving the battle critical ground attrition place and time can be used to quickly focus a dynamic battle into one of its critical static points. This methodology can be modified for other critical event places and times of the battle; relating for instance direct or indirect firing events, or command and control decision nodes.
- The critical ground attrition place and time graphics, especially the relative surface density and contour plots could be used in NTC After Action Reviews and for any type of combat simulation results to graphically enhance the learning process of "what happened" and help determine "why it happened."

The following is a discussion of possible follow-on topics to this thesis. This analysis deals with quantifying and analyzing ground force concentration, or mass, at a critical time in the battle. In the broader sense, this mass is just part of a unit's momentum (mass x velocity). A methodology which could dynamically monitor a unit's changing measure of mass and momentum during the battle could be used to check the relationship between momentum and mission MOEs. If relationships were found in such an analysis, the dynamic monitoring of unit momentum during the battle could serve as a major component in a commander's tactical decision aid.

The application of the critical attrition point method to other tactical analysis is definitely possible. This methodology allows the analyst to focus the battle, based on selected event criteria, and then three-dimensionally view the areas of highest relative event density. Events could take the form of attrition, indirect or direct fires, or command and control nodes. Using three dimensional event densities, associated with both a place and time could enhance ongoing work in the area of mathematically comparing computer models to exercise data, using nonlinear statistical mechanics [Ref. 13].

Since there is a discrepancy between NTC instrumented data and actual mission results, "qualification" of the database, to include the logical addition of missing vehicles and routes is an ongoing project at the ARI-POM CTC Archive. Further work is essential in order to relate NTC data to high resolution combat models, such as Janus and to unit combat simulators, such as SIMNET.

Analysis on unit training and performance at the Army's Advanced Collective Training Centers, such as NTC, is an ongoing mission of ARI's Presidio of Monterey Field Unit (ARI-POM). Part of this effort is a unit effectiveness measurement system at NTC, being developed by resident contract personnel at ARI-POM [Ref. 7]. Further work is needed to quantify mission measures of effectiveness and the collective tasks that make up these missions.

Finally, the concept of testing and enhancing high resolution combat models, such as Janus, and unit combat simulators with data from large-scale combat simulations is in its infancy. The potential exists to develop and test parameters related to human factors, such as fatigue, intelligence levels, and training proficiency in controlled simulations and then compare these results using a "reality check" from training centers, such as NTC.

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APPENDIX A: SCREENED KILL VEHICLE FORTRAN/EQUEL PROGRAM

```
      Program SKET

C     ROUTINE NAME:      SKET
C     AUTHOR:            CPT DAVID A. DRYER    U.S. ARMY
C     ASSISTED BY:       JACK BALDWIN   BDM CORPORATION
C     DATE:              1 AUGUST 1989
C     PURPOSE:
C     This program tailors the kill data from the PET and PSUT and increases its
C     accuracy in the following ways. Only BLUEFOR tank and mounted TOW
C     system kills, and OPFOR T-72 and BMP kills are considered. Actual
C     start and change of mission times are user inputs and kill events are only
C     recorded during this actual mission time period. A vehicle is permanently killed
C     after it is first killed in the PET table or it receives a PSTAT in the PSUT table of
C     "2" (combat loss), "3" (OC gun kill), or "5" (administrative kill). A PSTAT
C     "3" (accidental kill) is not considered a valid kill.

C     PET and PSUT arrays of length 400 (indexed on the unique armored tank
C     killing vehicle lpns) are created for each output data category listed below.
C     First time killed vehicles in either the PET or PSUT have their array entries
C     updated. PET and PSUT arrays are then compared and if a vehicle does not
C     incur a PET kill, the PSUT array is checked for a valid kill code and this PSUT
C     data is used in the output listing. The kill events in the PSUT table do not list an
C     associated location. Therefore, the program searches the GPLT to find the
C     vehicle's location within one GPLT time increment of the kill time in the PSUT.

C     USER INPUT: Mission Number, Actual Mission Start Time and Actual
C                 Mission End Time
C     OUTPUT:     Table Listing of Screened Kill Event Data consisting of:
C                        Decimal Kill Time                [itime(i)],
C                        Integer Kill Time                [petintime(i)],
C                        Vehicle LPN                      [pet_tlpn(i)],
C                        Vehicle Side                     [psit_side(i)],
C                        Vehicle Type                     [psit_ptype(i)],
C                        Vehicle Description              [pvwt_pveh1(i)],
C                        Vehicle Bumper Number            [pet_tpid(i)],
C                        PET or PSUT Kill Result          [pet_result(i)],
C                        Fratricide Status if PET Kill    [pet_frat(i)],
C                        Vehicle Location X Coordinate    [pet_tx(i)],
C                        Vehicle Location Y Coordinate    [pet_ty(i)]
```

```
##  declare
##  character*20     pet_time(400), p_time
##  integer*4        petintime(400), ihh, imm, iss
##  real*4           itime(400), jtime(400)
##  real*4           gtime(400)
##  integer*4        jinttime(400), jhh, jmm, jss
##  integer*4        ginttime(400), ghh, gmm, gss
##  character*3      pet_tpid(400), p_tpid, s_pid
##  integer*4        pet_tlpn(400), p_tlpn
##  integer*4        pet_tx(400), p_tx
##  integer*4        pet_ty(400), p_ty
##  character*1      pet_frat(400), p_frat
##  character*1      pet_result(400), p_result
##  character*1      psit_side(400), s_side
##  character*2      psit_ptype(400), s_ptype
##  character*15     pvwt_pveh1(400), pvwt_pveh2(400), v_pveh1, v_pveh2
##  character*15     v_pveh
##  integer*4        psut_lpn(400), u_lpn
##  character*3      psut_pid(400), u_pid
##  character*1      psut_side(400), u_side
##  character*20     psut_time(400), u_time
##  character*2      psut_ptype(400), u_ptype
##  character*1      psut_pstat(400), u_pstat
##  character*20     g_time
##  integer*4        gplt_x(400), g_x
##  integer*4        gplt_y(400), g_y
##  integer*4        g_pllpn
##  character*10     dbname(50)
##  integer*4        stime(50)
##  integer*4        ftime(50)
    character*50     filename

    jknt = 0

C   Input Mission Number, Actual Mission Start Time and Mission End Time...

    do j = 1, 50
       type *, 'input dbname (ie. MA870212 or "//" after last mission input):'
       read (*,10) dbname(j)
       if (dbname(j) .eq. '//') go to 15
       type *, 'input actual mission start time (ie. 0600):
       read (*,12) stime(j)
       type *, 'input actual mission change of mission time (ie. 0913):
       read (*,12) ftime(j)
       jknt = jknt + 1
10     format(a10)
```

```
 12     format(i4)
        enddo
 15  continue

     do l = 1, jknt

##   INGRES dbname(l)

C    Initialize selected arrays to default values...

     do i = 1,400
        pet_time(i) = ' '
        psut_time(i) = ' '
        psut_pstat(i) = ' '
        gplt_x(i) = 80001
        gplt_y(i) = 70001
        pet_tx(i) = 80001
        pet_ty(i) = 70001
     enddo

C    Check PET for first occurrence of selected vehicle kills within the boundaries of
C    the user input start and change of mission times, retrieve specified information
C    on these killed vehicles, and update PET arrays...

##   RANGE of p is PET
##   RANGE of s is PSIT
##   RANGE of v is PVWT

##   RETRIEVE  (p_time      =     p.time,
##              p_tpid      =     p.tpid,
##              p_tlpn      =     int4(p.tlpn),
##              p_tx        =     int4(p.tx),
##              p_ty        =     int4(p.ty),
##              p_frat      =     p.frat,
##              p_result    =     p.result,
##              s_ptype     =     s.ptype,
##              s_side      =     s.side,
##              v_pveh1     =     v.pveh)
##   WHERE      p.tlpn      =     s.lpn
##   AND        s.side      =     v.pside
##   AND        s.ptype     =     v.ptype
##   AND        (((s.side = "B") AND (s.ptype = "1" OR s.ptype = "3"
##   OR         s.ptype = "29"))
##   OR         ((s.side = "O") AND (s.ptype = "1" OR s.ptype = "2"
##   OR         s.ptype = "3" OR s.ptype = "4")))
##   AND        p.result = 'K'
##   SORT       #p_time
```

```
## {
    if (pet_time(p_tlpn) .eq. ' ') then
       pet_time(p_tlpn) = p_time
 50    format(i2)
       decode(2,50,p_time(12:13))ihh
       decode(2,50,p_time(15:16))imm
       decode(2,50,p_time(18:19))iss
       itime(p_tlpn) = ihh + (imm/60.) + (iss/3600.)
       petintime(p_tlpn) = (ihh * 10000) + (imm * 100)
   +                               + iss
    if ((petintime(p_tlpn) .ge. (stime(l) * 100))
   +           and. (petintime(p_tlpn) .le. (ftime(l) * 100)))
   +   then
       pet_tpid(p_tlpn) = p_tpid
       pet_tlpn(p_tlpn) = p_tlpn
       pet_tx(p_tlpn) = p_tx
       if (p_ty .lt. 70000) p_ty = p_ty + 100000
               pet_ty(p_tlpn) = p_ty
               psit_side(p_tlpn) = s_side
               psit_ptype(p_tlpn) = s_ptype
               pvwt_pveh1(p_tlpn) = v_pveh1
               pet_frat(p_tlpn) = p_frat
               pet_result(p_tlpn) = p_result

       endif

    endif
## }

C   Check PSUT for first occurrence of selected vehicle valid kill code within the
C   boundaries of the user input start and change of mission times, retrieve specified
C   information on these kill status vehicles and update PSUT arrays...

## RANGE of s is PSIT
## RANGE of v is PVWT
## RANGE of u is PSUT
## RETRIEVE   (u_lpn        =    int4(u.lpn),
##              u_pid        =    u.pid,
##              u_side       =    u.side,
##              u_time       =    u.time,
##              u_pstat      =    u.pstat,
##              u_ptype      =    u.ptype,
##              s_side       =    s.side,
##              v_pveh2      =    v.pveh)
## WHERE        u.lpn        =    s.lpn
## AND          s.side       =    u.side
## AND          s.ptype      =    v.ptype
```

```
## AND             s.side          =       v.pside
## AND             (((s.side = "B") AND (s.ptype = "1" OR s.ptype = "3"
## OR              s.ptype = "29"))
## OR              ((s.side = "O") AND (s.ptype = "1" OR s.ptype = "2"
## OR              s.ptype = "3" OR s.ptype = "4")))
## AND             (u.pstat = "2" OR u.pstat = "3"
## OR u.pstat = "5")
## SORT  #u_time
## {
    if (psut_time(u_lpn) .eq. ' ') then
       decode(2,50,u_time(12:13))jhh
       decode(2,50,u_time(15:16))jmm
       decode(2,50,u_time(18:19))jss
       jtime(u_lpn) = jhh + (jmm/60.) + (jss/3600.)
       jinttime(u_lpn) = (jhh * 10000) + (jmm * 100) + jss
       if (((jinttime(u_lpn) .ge. (stime(l) * 100))
   +                 and. (jinttime(u_lpn) .le. (ftime(l) * 100))))
   +          then
              psut_time(u_lpn) = u_time
              psut_lpn(u_lpn) = u_lpn
              psut_pid(u_lpn) = u_pid
              psut_side(u_lpn) = u_side
              psut_ptype(u_lpn) = u_ptype
              pvwt_pveh2(u_lpn) = v_pveh2
              psut_pstat(u_lpn) = u_pstat
       endif
    endif
## }

C   Since the kill events in the PSUT table do not list an associated player location,
C   search the GPLT for each valid PSUT kill to find the vehicle's location within
C   one GPLT time increment of the kill time in the PSUT...

## RANGE of g is GPLT
## RANGE of s is PSIT
## RANGE of u is PSUT

## RETRIEVE  (g_pllpn       =       int4(g.pllpn),
##                g_time        =       g.time,
##                g_x           =       int4(g.x),
##                g_y           =       int4(g.y))
## WHERE          u.lpn         =       g.pllpn
## AND            s.lpn         =       u.lpn
## AND            (((s.side = "B") AND (s.ptype = "1" OR s.ptype = "2"
## OR             s.ptype = "3" OR s.ptype = "29"))
## OR             ((s.side = "O") AND (s.ptype = "1" OR s.ptype = "2"
## OR             s.ptype = "3" OR s.ptype = "4")))
```

```
## AND            (u.pstat = "2" OR u.pstat = "3"
## OR u.pstat = "5")
## SORT #g_time
## {
    decode(2,50,g_time(12:13))ghh
    decode(2,50,g_time(15:16))gmm
    decode(2,50,g_time(18:19))gss
    gtime(g_pllpn) = ghh + (gmm/60.) + (gss/3600.)
    ginttime(g_pllpn) = (ghh * 10000) + (gmm * 100) + gss
    if (((jtime(g_pllpn) + 2.5/60.) .ge.
  +          gtime(g_pllpn))
  +          .and. ((jtime(g_pllpn) - 2.5/60.) .le.
  +          gtime(g_pllpn)))
  +   then
      gplt_x(g_pllpn) = g_x
      if (g_y .lt. 70000) g_y = g_y+100000
      gplt_y(g_pllpn) = g_y
    endif
## }

## EXIT

C   If a vehicle does have a valid PET kill recorded in its PET array, check the
C   PSUT array for a valid kill code.  If a PSUT kill exists for the vehicle, add this
C   data to the PET arrays...

    do i =  1, 400
      if ((pet_ty(i) .eq. 70001) .and. (psut_pstat(i) .ne. ' '))
  +          then
             petintime(i) = jinttime(i)
             itime(i) = jtime(i)
             pet_tpid(i) = psut_pid(i)
             pet_tlpn(i) = psut_lpn(i)
             pet_tx(i) = gplt_x(i)
             pet_ty(i) = gplt_y(i)
             psit_side(i) = psut_side(i)
             psit_ptype(i) = psut_ptype(i)
             pvwt_pveh1(i) = pvwt_pveh2(i)
             pet_frat(i) = ' '
             pet_result(i) = psut_pstat(i)
    endif
    enddo

C   Create SKET Output Table Listing (ie. MA870212.dat1;1)...

    filename = dbname(l) // '.dat1'
    open (unit=10,file=filename,status='NEW')
```

```
100     format(f8.4,1x,i6,1x,i3,1x,a1,1x,a2,1x,a15,1x,a3,1x,a1,1x,a1,1x,
  +          i6,1x,i6)
   do i = 1, 400
      if (pet_ty(i) .ne. 70001) then
             write(10,100) itime(i),
  +                 petintime(i),
  +                 pet_tlpn(i),
  +                 psit_side(i),
  +                 psit_ptype(i),
  +                 pvwt_pveh1(i),
  +                 pet_tpid(i),
  +                 pet_result(i),
  +                 pet_frat(i),
  +                 pet_tx(i),
  +                 pet_ty(i)
      endif
   enddo
   close(unit=10)
   enddo
   stop
   end
```

APPENDIX B: SCREENED GROUND PLAYER LOCATION FORTRAN/EQUEL PROGRAM

```
      Program SGPLT

C     ROUTINE NAME:   SGPLT
C     AUTHOR:         CPT DAVID A. DRYER    U.S. ARMY
C     ASSISTED BY:    JACK BALDWIN          BDM CORPORATION
C     DATE:           1 AUGUST 1989
C     PURPOSE:
C     This program tailors player location data from the GPLT at a user specified time
C     in the battle using the following techniques. Only BLUEFOR tank and
C     mounted TOW system locations and OPFOR T-72 and BMP locations are
C     considered. The input critical time is compared to the interval times in the
C     GPLT. This critical time is bracketed on both sides by GPLT times and then a
C     linear interpolation of both the X and Y grid coordinates is calculated, based on
C     time interval ratios. This provides a more accurate vehicle location at this critical
C     time, instead of just using the closest interval time in the GPLT. Each vehicle is
C     compared to the Screened Kill Event Table to determine whether it is alive or
C     has a PET or PSUT kill status at the user input time.

C     IMPORTANT NOTE: A mission's SKET file (i.e., MA870212.dat1;1) has to
C     be generated before executing this program.

C     USER INPUT: Mission Number, Battle Time, Mission Date, and Ground Log
C                 Interval
C     OUTPUT:     Table Listing of Screened Ground Player Location Data
C                 consisting of:
C                          Decimal Input Time                  [inptime(l)],
C                          Integer Input Time                  [inp_time(l)],
C                          Vehicle LPN                         [out_lpn(i)],
C                          Vehicle Side                        [out_side(i)],
C                          Vehicle Type                        [out_ptype(i)],
C                          Vehicle Description                 [out_pveh(i)],
C                          Vehicle Bumper Number               [out_pid(i)],
C                          Vehicle Status - Live or Kill Result [out_result(i)],
C                          Vehicle Location X Coordinate       [out_x(i)],
C                          Vehicle Location Y Coordinate       [out_y(i)]

##    declare
##    real*4          itime(400), outime(400), gtime(400)
##    real*4          outimel(400), outimeu(400), ratio(400)
##    integer*4       petintime(400), out_time(400), ginttime(400)
```

```
## integer*4       inp_time(50)
## real*4          inptime(50)
## integer*4       pet_tlpn(400), out_lpn(400), pl_lpn
## character*1     psit_side(400), out_side(400), pl_side
## character*2     psit_ptype(400), out_ptype(400), pl_ptype
## character*15    pvwt_pveh(400), out_pveh(400), pl_pveh
## character*3     pet_tpid(400), out_pid(400), pl_pid
## character*1     pet_result(400), out_result(400)
## character*1     pet_frat(400), out_frat(400)
## integer*4       pet_tx(400), pl_x
## integer*4       pet_ty(400), pl_y
## real*4          out_x(400), out_y(400)
## integer*4       out_xl(400), out_yl(400)
## integer*4       out_xu(400), out_yu(400)
## character*50    filename
## character*10    dbname(50)
## character*8     chartime(50), lchartime(50), uchartime(50)
## integer*4       ihour(50), imin(50), isec(50)
## integer*4       uhour(50), umin(50), usec(50), uppertime(50)
## integer*4       lhour(50), lmin(50), lsec(50), lowertime(50)
## integer*4       ghh, gmm, gss
## character*9     mdate(50)
## character*20    timechk(50), ltimechk(50), utimechk(50)
## character*20    pl_time
## integer*4       gndlog(50), num_kill
## character*11    start(50)
## integer*4       i, j, k, l, m, num_reps

      jknt = 0

C     Input Mission Number, Battle Time, Mission Date, and Ground Log Interval...

      do j = 1, 50
         type *, 'input dbname:'
         read (*,10)  dbname(j)
         if (dbname(j) .eq. '//') go to 15
         type *, 'input plot time (HH:MM:SS):'
         read (*,12)  chartime(j)
         type *, 'input mission date (ie. 02 Oct 86):'
         read (*,14)  mdate(j)
         type *, 'input gndlog in secs (300):'
         read (*,16) gndlog(j)

C     Convert input date/time into INGRES character string [timechk(j)].  Create
C     upper and lower bound by adding and subtracting ground log interval to input
C     time and convert these to INGRES character strings [utimechk(j)] and
C     [ltimechk(j)] respectively...
```

```
      start(j) = ' ' // mdate(j) // ' '
      decode(8,20,chartime(j))ihour(j),imin(j),isec(j)
      inp_time(j) = (ihour(j) * 10000) + (imin(j) * 100)
     +                         + isec(j)
      inptime(j) = ihour(j) + (imin(j)/60.) + (isec(j)/3600.)
      timechk(j) = start(j) // chartime(j) // ' '
      uppertime(j) = ihour(j)*3600 + imin(j)*60
     +                         + isec(j) + gndlog(j)
      uhour(j) = uppertime(j)/3600
      umin(j) = (uppertime(j) - uhour(j)*3600)/60
      usec(j) = (uppertime(j) - uhour(j)*3600 - umin(j)
     +                         *60)
      encode(8,20,uchartime(j)) uhour(j),umin(j),usec(j)
      utimechk(j) = start(j) // uchartime(j) // ' '
      lowertime(j) = ihour(j)*3600 + imin(j)*60
     +                         + isec(j) - gndlog(j)
      lhour(j) = lowertime(j)/3600
      lmin(j) = (lowertime(j) - lhour(j)*3600)/60
      lsec(j) = (lowertime(j) - lhour(j)*3600 - lmin(j)
     +                         *60)
      encode(8,20,lchartime(j)) lhour(j),lmin(j),lsec(j)
      ltimechk(j) = start(j) // lchartime(j) // ' '
      jknt = jknt + 1
 10   format(a10)
 12   format(a8)
 14   format(a9)
 16   format(i3)
 20   format(i2.2,':',i2.2,':',i2.2)
    enddo
 15 continue

C   Initialize selected arrays to default values...

    do k = 1, 400
      out_yl(k) = 70001
      out_result(k) = 'L'
      out_frat(k) = ' '
    enddo
    num_reps = 0

C   Read mission's SKET file listing...

    do l = 1, jknt
      filename = dbname(l) // '.dat1'
      open (unit = 10, file=filename,status='OLD')
 100  format  (f8.4,1x,i6,1x,i3,1x,a1,1x,a2,1x,a15,1x,a3,1x,a1,
```

```
   +           1x,a1,1x,i6.1,1x,i6)
    num_kill = 0
       do i = 1, 400
       read (10,100,end=40)  itime(i),
   +           petintime(i),
   +           pet_tlpn(i),
   +           psit_side(i),
   +           psit_ptype(i),
   +           pvwt_pveh(i),
   +           pet_tpid(i),
   +           pet_result(i),
   +           pet_frat(i),
   +           pet_tx(i),
   +           pet_ty(i)
       num_kill = num_kill + 1
       enddo
 40 continue
    close(unit=10)

C   Select the low GPLT time by bracketing it with the input time [timechk (j)] and
C   the lower time [ltimechk(j)].  Retrieve specified vehicle information, including X
C   and Y location, at this low GPLT time and update low arrays...

##  INGRES dbname(l)
##  RANGE of g is GPLT
##  RANGE of s is PSIT
##  RANGE of v is PVWT

##  RETRIEVE   (pl_time      =     g.time,
##               pl_pid       =     g.plpid,
##               pl_side      =     s.side,
##               pl_lpn       =     int4(g.pllpn),
##               pl_ptype     =     v.ptype,
##               pl_pveh      =     v.pveh,
##               pl_x         =     int4(g.x),
##               pl_y         =     int4(g.y) )
##  WHERE        g.pllpn      =     s.lpn
##  AND          g.time       <=    timechk(l)
##  AND          g.time       >     ltimechk(l)
##  AND          v.ptype      =     s.ptype
##  AND          v.pside      =     s.side
##  AND          (((s.side = "B") AND (s.ptype = "1" OR s.ptype = "3"
##  OR           s.ptype = "29"))
##  OR           ((s.side = "O") AND (s.ptype = "1" OR s.ptype = "2"
##  OR s.ptype = "3" OR s.ptype = "4")))
##  {
 50 format(i2)
```

```
      decode(2,50,pl_time(12:13))ghh
      decode(2,50,pl_time(15:16))gmm
      decode(2,50,pl_time(18:19))gss
      gtime(pl_lpn) = ghh + (gmm/60.) + (gss/3600.)
      ginttime(pl_lpn) = (ghh * 10000) + (gmm * 100) + gss
      out_lpn(pl_lpn) = pl_lpn
      outimel(pl_lpn) = gtime(pl_lpn)
      out_time(pl_lpn) = ginttime(pl_lpn)
      out_side(pl_lpn) = pl_side
      out_ptype(pl_lpn) = pl_ptype
      out_pveh(pl_lpn) = pl_pveh
      out_pid(pl_lpn) = pl_pid
      out_xl(pl_lpn) = pl_x
      if (pl_y .lt. 70000) pl_y = pl_y + 100000
      out_yl(pl_lpn) = pl_y
##  }

C   Select the high GPLT time by bracketing it with the input time [timechk (j)] and
C   the upper time [utimechk(j)].  Retrieve specified vehicle information, including
C   X and Y location, at this high GPLT time and update high arrays...

##  RANGE of g is GPLT
##  RANGE of s is PSIT
##  RANGE of v is PVWT
c
##  RETRIEVE   (pl_time     =     g.time,
##                pl_pid      =     g.plpid,
##                pl_side     =     s.side,
##                pl_lpn      =     int4(g.pllpn),
##                pl_ptype    =     v.ptype,
##                pl_pveh     =     v.pveh,
##                pl_x        =     int4(g.x),
##                pl_y        =     int4(g.y) )
##  WHERE         g.pllpn     =     s.lpn
##  AND           g.time      >=    timechk(l)
##  AND           g.time      <     utimechk(l)
##  AND           v.ptype     =     s.ptype
##  AND           v.pside     =     s.side
##  AND           (((s.side = "B") AND (s.ptype = "1" OR s.ptype = "3"
##  OR            s.ptype = "29"))
##  OR            ((s.side = "O") AND (s.ptype = "1" OR s.ptype = "2"
##  OR            s.ptype = "3" OR s.ptype = "4")))
##  {
      decode(2,50,pl_time(12:13))ghh
      decode(2,50,pl_time(15:16))gmm
      decode(2,50,pl_time(18:19))gss
      gtime(pl_lpn) = ghh + (gmm/60.) + (gss/3600.)
```

```
      ginttime(pl_lpn) = (ghh * 10000) + (gmm * 100) + gss
      out_lpn(pl_lpn) = pl_lpn
      outimeu(pl_lpn) = gtime(pl_lpn)
      out_time(pl_lpn) = ginttime(pl_lpn)
      out_side(pl_lpn) = pl_side
      out_ptype(pl_lpn) = pl_ptype
      out_pveh(pl_lpn) = pl_pveh
      out_pid(pl_lpn) = pl_pid
      out_xu(pl_lpn) = pl_x
      if (pl_y .lt. 70000) pl_y = pl_y + 100000
      out_yu(pl_lpn) = pl_y
## }

C     Calculate interpolation ratio, based on the input time relation to the GPLT high
C     and low times.  Use this ratio to conduct linear interpolation on X and Y location
C     coordinates using high and low values...

## EXIT
      do i = 1,400
         if (out_yl(i) .ne. 70001) then
                ratio(i) = ((inptime(l) - outimel(i))/
   +                         (outimeu(i) - outimel(i)))
                out_x(i) = (out_xl(i) +
   +                         (ratio(i) * (out_xu(i) - out_xl(i))))
                out_y(i) = (out_yl(i) +
   +                         (ratio(i) * (out_yu(i) - out_yl(i))))
         endif
      enddo

      do i = 1,num_kill
         do m = 1,400
         if ((pet_tlpn(i) .eq. out_lpn(m))
   +                  .and. (petintime(i) .le. out_time(m)))
   +            then
                out_result(m) = pet_result(i)
                out_frat(m) = pet_frat(i)
         endif
         enddo
      enddo

C     Create SGPLT Output Table Listing (ie. MA870212.live1;1)...

      filename = dbname(l) //'.live1'
      open (unit=10,file=filename,status='NEW')
 200     format  (f7.4,1x,i6,1x,i3,1x,a1,1x,a2,1x,a15,1x,a3,1x,a1,
   +            1x,a1,1x,f8.1,1x,f8.1)
      do i = 1,400
```

```
 if ((out_yl(i) .ne. 70001)
+             .and. (out_yl(i) .ne. 70000))
 then
    write (10,200) inptime(l),
+             inp_time(l),
+             out_lpn(i),
+             out_side(i),
+             out_ptype(i),
+             out_pveh(i),
+             out_pid(i),
+             out_result(i),
+             out_frat(i),
+             out_x(i),
+             out_y(i)
 endif
 enddo
 close (unit=10)
 enddo
 stop
 end
```

APPENDIX C: ATTRITION SURFACE DENSITY GRAFSTAT/APL FUNCTIONS

THIS IS THE ORIGINAL FUNCTION IN GRAFSTAT/APL WHICH CALCULATES THE BIVARIATE SURFACE DENSITY MATRIX. THE CALCULATION OF THIS MATRIX IS EXPLAINED IN CHAPTER VII, SECTION A. THE USER SPECIFIED INPUTS ARE DONE USING A MENU IN THE GRAFSTAT ENVIRONMENT.

```
      ∇154DEN[⎕]
      ∇154DEN; X1; X2; Y1; Y2;J ; T1; T2;N
[1]     X2←⌈/ 154X
[2]     X1←⌊/ 154X
[3]     Y2←⌈/ 154Y
[4]     Y1←⌊/ 154Y
[5]    N ←''ρρ 154X
[6]     154SURF←( 154XG, 154YG)ρ0
[7]     154XV←( X1- 154XW×0.6)+(÷ 154XG-1)×(0,ι 154XG-1)×(1.2× 154XW)+ X2- X1
[8]     154YV←( Y1- 154YW×0.6)+(÷ 154YG-1)×(0,ι 154YG-1)×(1.2× 154YW)+ Y2- Y1
[9]    J ←1
[10]  L 1:
[11]    T1←(( 154XV≥ 154X[J ]- 154XW÷2)∧( 154XV≤ 154X[J ]+ 154XW÷2))/ι 154XG
[12]   →(0=ρ T1)/L 2
[13]    T2←(( 154YV≥ 154Y[J ]- 154YW÷2)∧( 154YV≤ 154Y[J ]+ 154YW÷2))/ι 154YG
[14]   →(0=ρ T2)/L 2
[15]    154SURF[ T1; T2]← 154SURF[ T1; T2]+ 154W[J ]×1+2○○1⌊2×(((( 154XV[ T1]- 1
      54X[J ])÷ 154XW)*2)∘.+((¯154YV[ T2]- 154Y[J ])÷ 154YW)*2)*0.5
[16]    154SURF[ T1; T2]← 154SURF[ T1; T2]- 154W[J ]×1+2○○1⌊2×(((( 154XV[ T1]- 1
      54X[J ])÷ 154XW)*2)∘.+((¯154YV[ T2]- 154Y[J ])÷ 154YW)*2)*0.5
[17]  L 2:
[18]   →(N ≥J ←J +1)/L 1
[19]    154SURF←⍉ 154SURF×4÷ 154XW× 154YW×(+/ 154W)×(○1)-2
```

APL FUNCTION RELDENS IS A MODIFICATION OF THE ORIGINAL GRAFSTAT/APL FUNCTION WHICH CALCULATES THE BIVARIATE SURFACE DENSITY MATRIX. RELDENS SEPARATES BLUE AND OPFOR KILLS WITH BOOLEAN VECTORS. AT EACH OPFOR KILL LOCATION A RAISED COSINE BELL IS PLACED. AT EACH BLUEFOR KILL LOCATION A LOWERED COSINE BELL IS PLACED. THE RESULTING SURFACE IS THE CUMULATIVE AREA OF THESE COSINE BELLS.

```
      ∇RELDENS[⎕]
      ∇ RELDENS; X1; X2; Y1; Y2;J ; T1; T2;N
[1]     X2←⌈/ 154X
[2]     X1←⌊/ 154X
[3]     Y2←⌈/ 154Y
[4]     Y1←⌊/ 154Y
[5]    N ←''ρρ 154X
[6]     154SURF←( 154XG, 154YG)ρ0
[7]     154XV←( X1- 154XW×0.6)+(÷ 154XG-1)×(0,ι 154XG-1)×(1.2× 154XW)+ X2- X1
[8]     154YV←( Y1- 154YW×0.6)+(÷ 154YG-1)×(0,ι 154YG-1)×(1.2× 154YW)+ Y2- Y1
[9]    J ←1
[10]  L 1:
[11]    T1←(( 154XV≥ 154X[J ]- 154XW÷2)∧( 154XV≤ 154X[J ]+ 154XW÷2))/ι 154XG
[12]   →(0=ρ T1)/L 2
[13]    T2←(( 154YV≥ 154Y[J ]- 154YW÷2)∧( 154YV≤ 154Y[J ]+ 154YW÷2))/ι 154YG
[14]   →(0=ρ T2)/L 2
[15]   →(BOOLSIDE1[J ]=1)/L3
[16]   →(BOOLSIDE2[J ]=1)/L
[17]   →L 2
[18]  L:
[19]    154SURF[ T1; T2]← 154SURF[ T1; T2]+ 154W[J ]×1+2○○1⌊2×(((( 154XV[ T1]- 1
      54X[J ])÷ 154XW)*2)∘.+((¯154YV[ T2]- 154Y[J ])÷ 154YW)*2)*0.5
[20]   →L 2
[21]  L3:
[22]    154SURF[ T1; T2]← 154SURF[ T1; T2]- 154W[J ]×1+2○○1⌊2×(((( 154XV[ T1]- 1
      54X[J ])÷ 154XW)*2)∘.+((¯154YV[ T2]- 154Y[J ])÷ 154YW)*2)*0.5
[23]  L 2:
[24]   →(N ≥J ←J +1)/L 1
[25]    154SURF←⍉ 154SURF×4÷ 154XW× 154YW×(+/ 154W)×(○1)-2
      ∇
[26]  ∇
```

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